IMPROVEMENT OF CONCENTRATED FEED CONVEYER OPERATION EFFICIENCY

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Abstract. The paper deals with the research in concentrated feed conveyer productivity based on the constructive solutions of the conveyer. The research is performed in a laboratory using a spiral conveyer based for cow feeding and made by the *DeLaval, Inc.* For the purpose of this experimental research the conveyer is combined and transformed into a snail conveyer. During the research the authors established that the conveyer productivity changes at the constant pitch angles if the conveyer mode is changed. Thus, for example, the conveyer in a spiral conveyer mode at the uplift of 0 degree is more productive than a conveyer in a snail conveyer mode whereas at the uplift angle above 20 degrees the conveyer in the snail conveyer mode is more efficient than the spiral conveyer. This peculiarity results due to the backward pour out of the conveyed load through the middle part of the spiral.

Key words: cow feeding, snail conveyer, conveyer optimization, concentrated feed stations.

Introduction

Concentrated feed has very vital significance in feeding of domestic animals such as birds, pigs and cattle. They may be fed in different ways inter alia by animal feeding precise technology. Usually such feed is prepared in a granulated shape for the reason that it is more compact and takes less place; while during over pouring and conveying it makes less dust thus reducing mechanical losses. Moreover, such feed is more fireproof as well.

Periodically the concentrated feed is carried next to the animal dwelling and stored in special containers. Then using different stationary conveyers it is delivered to the feeding places. The paper also deals with the research of the concentrated feed conveyer operation mode depending on the conveyer constructive solutions using conveyers in a spiral conveyer and a snail conveyer mode. The authors have developed a methodology for calculation of the conveyer operation mode. The calculations are based on the coherences described in special literature [1]. For the specification of the theoretical statement and the verification of the elaborated methodology software MatLab Simulink is used.

Materials and methods

During the research the authors established that the conveyer productivity, the filling coefficient and the backward pour out of the transported concentrated feed depend on the conveyer pitch angle and a constructive solution. In a general case, the productivity of both the spiral conveyer and the snail conveyer is calculated according to the formula [1].

$$Q = 3600 \cdot k_r \cdot F_d \cdot v_{z.vid} \cdot \rho . \tag{1}$$

where Q – productivity of spiral conveyer, kg·h^{-1};
k_r – productivity coefficient;
F_d – internal crosscut area of conveyer flexible pipe, m^2;
$v_{z.vid}$ – average speed of material movement into direction of axis, m·s^{-1};
ρ – volumetric mass of conveyed material, kg·m^{-3}.

There is established a methodology for calculation of the filling amount in the spiral conveyer by using a definite integral which evaluates the conveyer unfulfilled area.

Taking into account the productivity coefficient observed in the special literature [1; 2] it is necessary to clarify its calculations for the conveyers in the spiral conveyer and the snail conveyer modes. Both, the theoretical and the experimental studies are necessary to establish the productivity coefficient [3].

In the theoretical studies expressions which evaluate mobile mass movement – backward pour out depending on the conveyer step, the pitch angle and the mobile mass natural spillage angle are taken as the base. There are mathematical patterns developed for treatment of the obtained expressions using software MatLab Simulink.

The experimental research is carried out in a laboratory equipped with a spiral conveyer test bench which is transformed into a snail conveyor. During the research the authors established the conveyer actual productivity as well as the pipe filling coefficient of the conveyer. The methodology of the experimental research is as follows.

- Charges conveyer and defines its productivity in a specific unit of time in both the snail conveyer and the spiral conveyer modes and at different transportation pitch angles.
- Discharges the whole feed from the conveyer (in both constructive solutions) and weighs it.
- In the laboratory conditions defines the feed volumetric mass that is used for the purpose of the research.
- Calculates the conveyer filling coefficient consequently referring to a volume of discharged feed vs. a useful volume of the conveyer pipe, viz., the pipe volume wherefrom the taken volume of the spiral is deducted.
- Calculates the conveyer productivity by taking into account the experimentally obtained filling coefficient.
- The natural spillage angle of the conveyed feed is established by using a specially made device.

Results of the research

Taking into consideration expressions which are discussed in the special literature [1; 4; 5] for calculation of the conveyer filling it is necessary to evaluate the feed natural spillage angle. Information written in the special literature [1] depicts that if this angle is known then the inner friction coefficient of the feed particles in motion may be calculated according to the 2nd expression:

$$\beta = 0.7\psi \,, \tag{2}$$

where ψ – inner friction angle of mobile particles, in degrees;
β – inner friction coefficient of feed particles in motion, in degrees.

There is established a methodology for calculation of filling of the spiral conveyer by using the definite integral which evaluates the conveyer unfulfilled cross-cut area. The conveyer productivity is influenced by its filling coefficient at constant constructive parameters and the conveyer rotation frequency. Where φ_{sp} – the filling coefficient of the spiral conveyer and φ_{gl} – the filling coefficient of the snail conveyer. In order to obtain precise values of these coefficients more calculations are indispensable.

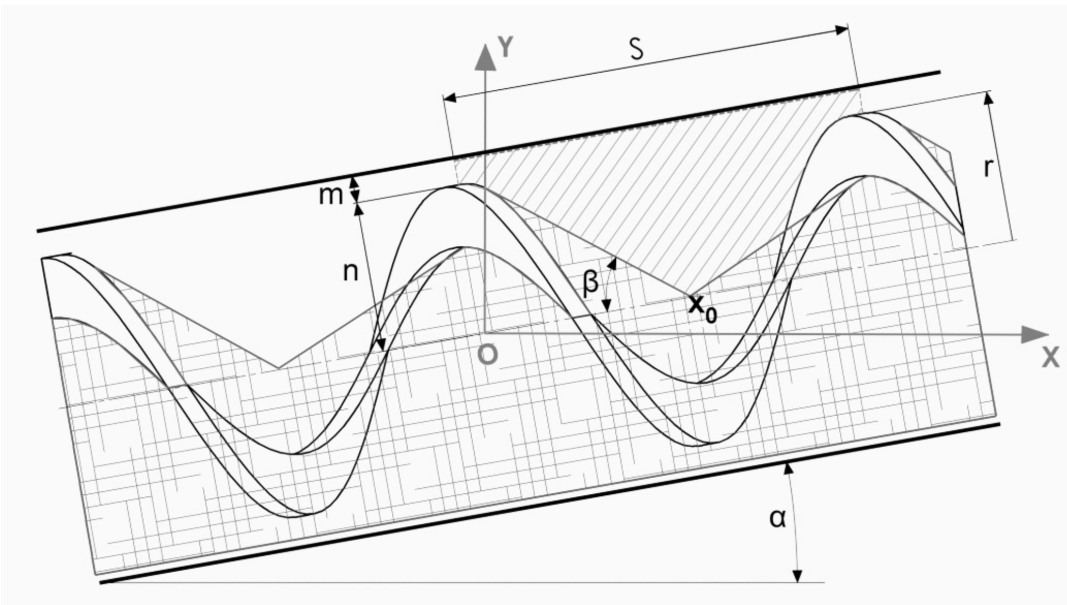

Fig. 1. **Scheme of calculation of snail conveyer filling:** n – height of spiral raker; m – space between raker upper edge and outer shell-pipe; β – inner friction coefficient of feed particles in motion; α – pitch angle of conveyer; 0-s – intermediate-step distance; $r = d$ – radius of spiral

Taking into account the area marked in Fig.1, the authors introduce mathematical expressions which characterise straight lines in the coordinate system in the general equation (1) and a coefficient *k*, which characterises a mobile feed spillage slope for the given area. The authors introduce a contingent system of straight lines in order to clarify the feed unfilled area. Whereas in order to clarify the equation of this same straight line the authors used an expression where: *k* – straight line angle tg; it is formed by the straight line and O_x axis positive direction and *b* – space on the O_y axis (in our case it is the length of the conveyer vane) (3).

$$y = b + k \cdot x . \tag{3}$$

The authors consider that an angle α is a pitch angle of the load, whereas an angle β is a natural spillage angle of the transported mass. If evaluating the coherence that the straight line goes through two pints, where the coordinates of the first point at the horizontal conveyer position are 0, then the variable is x_0. b – point of intersection with y axis. The straight line which characterises the marked area has diminishing direction, and then the point of intersection with the coordinate system y must be described according to the expression (4).

$$b = -k \cdot x_0 . \tag{4}$$

Using the methodology described above, we see that the coordinates of the variable point x_0 are characterised by the expression (5).

$$x_0 = \frac{d}{ctg(\beta - \alpha)} \tag{5}$$

By carrying on the calculations it is obvious that the expression (4) must be supplemented with the equation (5):

$$b = \frac{-k \cdot d}{ctg(\beta - \alpha)} \tag{6}$$

Whereas the direction coefficient k is defined by the expression 7:

$$k = ctg(\beta - \alpha) \tag{7}$$

Summarising all preceding calculations the authors obtain a straight line equation of analytical mathematics. This equation characterises the first straight line (feed spillage due to the influence of the natural spillage angle (inner friction force)). This straight line equation is written in the expression (8).

$$y_1 = r + ctg(\beta - \alpha) \cdot x \tag{8}$$

According to a similar coherence an expression for the second straight line is obtained, which characterises the amount of feed being over-spilled into the conveyer.

$$y_2 = -tg\alpha \cdot \frac{d}{ctg(\beta - \alpha)} + tg\alpha \cdot x \tag{9}$$

Wherewith, there are obtained both contingent straight line expressions, which must be inserted in the contingent integral formulas for calculation of an area. Initially by using the defined integral formula (10) the feed unfilled area is defined up to the contingent spillage end x_0 (x_0 – variable depending on both, lifting and spillage angles),

$$S_{bsp} = \int_0^{x_0} n + r - (r - ctg(\beta - \alpha) \cdot x)dx + \int_{x_0}^{s} \left(\frac{y_0(r - xctg(\beta - \alpha))}{s - ctg(\beta - \alpha) - r} \right) dx \tag{10}$$

where β – natural spillage angle;
α – conveyer uplift angle;
n – space between spiral tangent and conveyer pipe inner side, m;
r – spiral radius, m.

An equation (11) is compiled due to the simplification, via expression and transformation of the obtained expression.

$$S_{bsp} = \int_0^{x_0} n + ctg(\beta-\alpha)\cdot x)dx + \int_{x_0}^{s} (n + r + tg\alpha \cdot \frac{m}{ctg(\beta-\alpha)} - tg\alpha \cdot x)dx \quad (11)$$

where m – spiral raker height.

Where expressions (12) and (13) are obtained due to the integration

$$S_{bsp} = Dx\Big|_0^{x_0} + ctg(\beta-\alpha)\cdot \frac{x^2}{2}\Big|_0^{x_0} + (D + r + tg\alpha \cdot \frac{\alpha}{ctg(\beta-\alpha)})\cdot x\Big|_{x_0}^{s} - tg\alpha \cdot \frac{x^2}{2}\Big|_{x_0}^{s} \quad (12)$$

$$S_{bsp} = D\cdot x_0 + ctg(\beta-\alpha)\frac{x_0^{\ 2}}{2} + (D + r + tg\alpha \cdot \frac{r}{ctg(\beta-\alpha)})\cdot(s - x_0) - tg\alpha \cdot \frac{1}{2}\left(s^2 - x_0^{\ 2}\right) \quad (13)$$

Taking into account the expression (3) expressed above and putting it into the equation (8) an area expression (14) is obtained, which characterises the cross-cut area unfilled with the feed. This area forms in a vertical plane between two spiral winds.

$$S_{bsp} = n\cdot\frac{m}{ctg(\beta-\alpha)} + ctg(\beta-\alpha)\frac{m^2}{2ctg^2(\beta-\alpha)} + tg\alpha\cdot\frac{r}{ctg\beta} \quad (14)$$

Taking into consideration the cross-cut area of the conveyer pipe, expression (14); for calculation of the area it is necessary to fulfil it with the necessary expression. Also an expression must be taken into account that the filling coefficient characterises correlation of the taken and free area. The formula must be reduced according to a proper expression thus obtaining an equation (15) which expresses the filling coefficient for the spiral conveyer.

$$\varphi_{sp} = 1 - \frac{\frac{m\cdot n}{ctg(\beta-\alpha)} + \frac{m^2}{2ctg\ \ (\beta-\alpha)} + \frac{m\cdot tg\alpha}{ctg\beta}}{2\cdot(n+r)} \quad (15)$$

After a similar methodology also calculation of the filling coefficient for the snail conveyer is done by taking into account the situation when throughput of feed does not take place though a core of the conveyer takes some part of the conveyer productive capacity. The program MatLab Simmulink is used in order to compare both, the spiral and the snail conveyers. By using this program simulation is performed where the lifting angle is changed thus inspecting the theoretical productivity of the device which is set in the laboratory. As out-put parameters the ones which are defined in an experimental manner are used. Only the conveyer natural spillage angle β is defined in a theoretically static system and is calculated according to the 2nd formula as observed above.

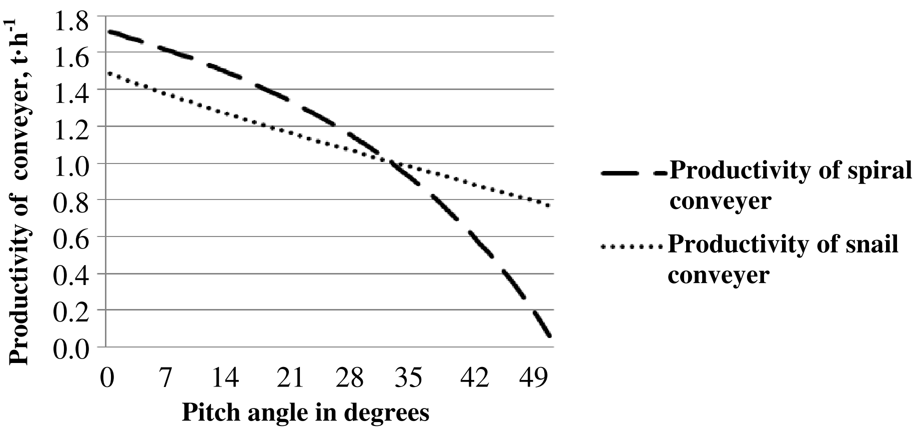

Fig. 2. **Theoretical productivity of snail conveyer and spiral conveyer; changing transportation angle at constant technical parameters**

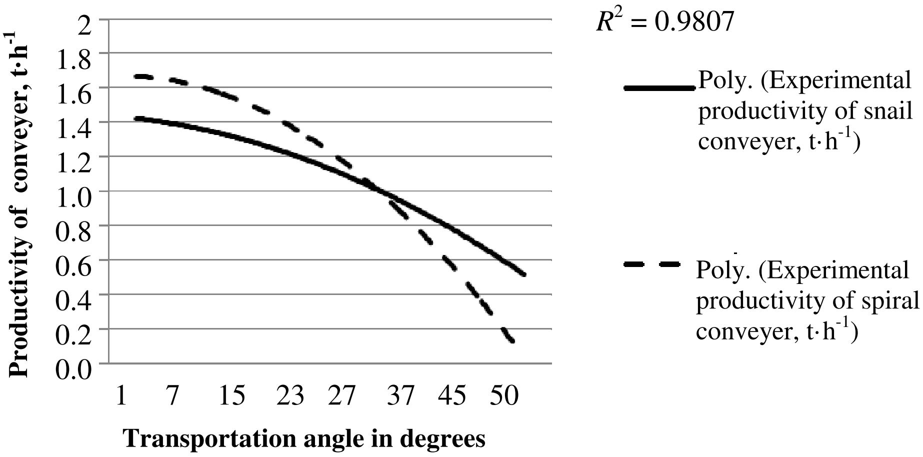

Fig. 3. **Experimental productivity of spiral conveyer and snail conveyer**

Consequently, for calculation of the theoretical productivity of the conveyer that is available for the research, it is necessary to define the feed density by an experimental manner. The density of concentrated feed is defined as 0.659829 $t \cdot m^{-3}$ with a standard error 0.007635 [6]. By using the expressions that are observed above the authors obtained a graphical productivity expression at constant technical parameters (they used the snail and the spiral conveyer). The characteristic values of productivity of these conveyers are displayed in Fig. 2.

Conclusions

1. The methodology of conveyer productivity calculation by using the integration method and the simulation program MatLab may be successfully applied and the obtained results comply with those that are obtained experimentally, for example, considering the existent parameters the productivity of both of these conveyers is equal near 29 degrees. The utmost productivity of the snail conveyer is approx. 1, 45 $t \cdot h^{-1}$ whereas the spiral conveyer may be used up to the pitch of 50 degrees.
2. It is efficient to use a conveyer in the regime of the spiral conveyer if the pitch angle of the conveyed load does not exceed 40 degrees.
3. Compared together, the spiral conveyer and the snail conveyer – in cases when the pitch angle is below 29 degrees the first conveyor is more effective whereas when above 29 degrees – the second one.
4. The productivity of the conveyers is vitally affected by the mobile feed natural spillage angle.
5. When designing conveyers it is essential to observe the spiral step and proportions of inner and outer diameters of the spiral.

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