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Design of material conveying by variable pipe conveyor

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Abstract. The latest requests for transport are based on cost, energy and material saving and also a very important request is an environmentally friendly transport system. One of these systems is presented by pipe conveyor and its modification - variable pipe conveyor. The paper presents the results of the part of a realized case study which includes the design of a variable pipe conveyor and associated calculations for the design of material conveying. The paper presents the selected part of the calculation, namely calculation of tensions in the conveyor belt, the spacing of idler rollers and solution of the dump.

1 Introduction

The result of the rapid development of industrialization and the development of society is also presented by a negative impact on the quality of the environment. Therefore it is needed to create ecologically less bad technological processes in each transport direction. Development in material transport leads up to new ecological transport devices and progressive technologies in the area of transport. Projection of new transport devices must regard the environmental factor and it is needed to develop transport technologies with new ecological orientation [1]. Development in this direction has not stopped and it is possible to monitor progressive innovated belt conveyors, such as variable pipe conveyors.

Variability of belt conveyors presents primarily a choice to select a suitable transport route, respectively modification, change of this route according to requirements. It is realized by the constructional design of variable belt conveyors of which main advantage is their flexibility and operational readiness for material unloading. Each variable belt conveyor is specific by its determination and implementation in the specific transport conditions. Components of belt conveyors must also correspond to these properties by their determination. An analysis of environmental requirements and properties of the conveyed material allows a right choice of components and design of the specific solution of a variable conveyor [2].

The limiting factor of the variable belt conveyor is the length of the transport route. Finding a solution for this limiting factor can be presented by the construction of pipe conveyors that allow changing the direction of transport with adaptation to the variability of

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the trajectory of transport during the operation. Variable pipe conveyors are the result of this requirement (for example uniform dumping of the conveyed material, or the requirement to change the place of the conveyed material dumping). The support construction of the variable system is designed for the possibility of displacement of idler rollers in the horizontal direction. Hopper and dumping stations are solved with a separate undercarriage with belt drive.

The mobile station can be powered by an electric drive or combustion unit. By changing of conveying direction, idler rollers realize a sliding movement by support plates. The advantage of this type of variable conveyor is the possibility of continuous leading of the transport trajectory/route also in arches. This function eliminates the limited length of transport of conventional variable conveyors. A combination of these benefits – the technology of pipe conveyor and variable conveyors significantly expanded the possibility of the belt conveying application for longer distances in a complicated terrain with a flexibly defined place of dumping [3].

The design of material conveying by variable pipe conveyor (Fig. 1) will be solved at the model situation of conveying Q = 450 $t.h^{-1}$ of the fly ash to the landfill by the designed conceptual solution. Volume conveying capacity will be Iv = 350 $m3.h^{-1}$. The conveying will be due to the possibility of the continuous dumping of the fly ash to the landfill in the curve-form. The total length of the conveying will be L = 200 m in a moderately incline at an angle $\partial = 3°$. The speed of the pipe conveyor will be v = 2 $m.s^{-1}$. And the powder density of the conveyed fly ash will be $\rho = 500$ $kg.m^{-3}$.

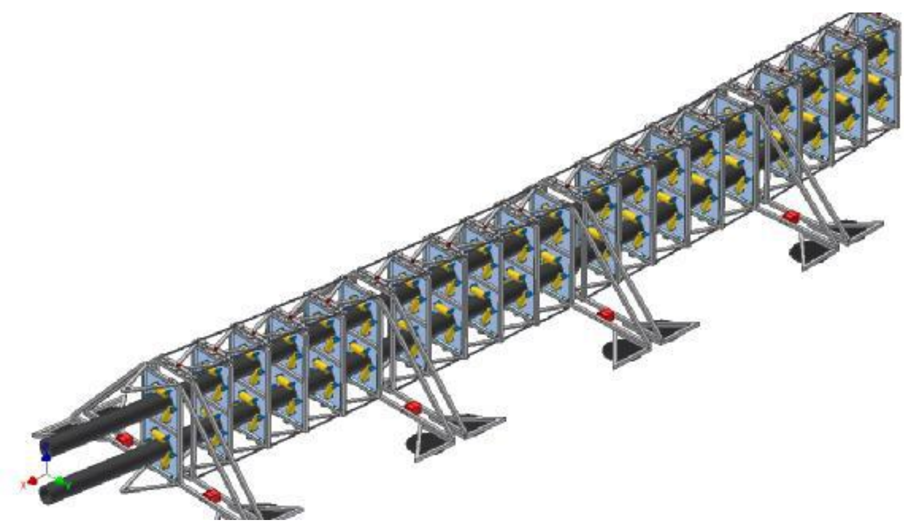

Fig. 1. Variable pipe conveyor. Source: [5]

2 Calculation of tensions in the conveyor belt

For safe and correct operation it is imperative that the peripheral drive forces on the drive drums were conveyed to the conveyor belt without slipping and also without significant slacks among idler rollers. For the circumferential driving force is needed to hold the tension force on the value by the equation [4]:

$$F_{2min} \geq F_{Umax} \frac{1}{e^{\mu \varphi_{b-1}}} \text{ [N]} \tag{1}$$

where: F_{Umax} – maximal circumferential force at start/brake of fully loaded conveyor [N], μ – coefficient of friction between the drum and conveyor belt 0.05 – 0.45, φ_b – the angle of contact of the driving drum 2.8 – 4.2 (160° – 240°). In the case of a slight inclination of the conveyor using of one driving drum and small braking forces to the belt stopping, it is possible to calculate the highest tensile force by the equation [5]:

$$F_{max} = F_1 = F_U.\xi.\left(\frac{1}{e^{\mu\varphi b}-1}+1\right) = 12405{,}699\,.\,2\,.\left(\frac{1}{e^{0{,}3-3{,}15}-1}+1\right) = 40586{,}567\ N \qquad (2)$$

where: ξ – coefficient taking into account the start of the belt conveyor 1.3 – 2 (taking into account the need for greater circumferential force at the conveyor start). According to the catalogue value of the unnamed company (producer of rubber belts in Slovakia) the conveyor belt with the marking ECOTUBELT F1: P 500/2 4+2, F1 meets the maximum tensile force in the conveyor belt.

3 The spacing of idler rollers

The spacing of idler rollers depending on the diameter of the rolled up pipe conveyor according to the [6] is presented by the following comparative table.

Table 1. Spacing of idler rollers. Source: [2]

Diameter of the pipe d [mm]	150	200	300	450
Spacing of idler rollers [m]	1,5	1,6	1,8	2,7

From the comparative table it is evident that for the calculated diameter of the pipe d = 215 mm, it is due the maximum spacing of the idler roller to 1,6 m.

4 A solution of the dump

At the point of the conveyed material dump, the conveyed particles change their direction and speed, and the trajectory after leaving of the reversible drum can be described by a parable. Their impact speed is described by the components in the direction v_x and v_y. The trajectory of the material (according to the point in which the material segregates from the reversible drum) can be described by the equation according to [5].

$$h_p = \frac{g.r_b^2}{v^2} = \frac{9{,}81.0{,}1575^2}{2^2} = 0{,}0608\ m \qquad (3)$$

Where: g - acceleration of gravity [m.s^{-2}], r_b – radius of the reversible drum [m], v – speed of the conveyed material [m.s^{-1}]. For the selected conveyor belt ECOTUBELT F1: P 500/2 4+2, F1 the diameters of the drums are: driving drum 400 mm, reversible drum 315 mm, r_b = 0,1575 m. Depending on the fact if the $h_p > r_b$ or $h_p < r_b$ it is possible to determine where the material separates from the reversible drum. In this case $h_p < r_b$, so the conveyed material will be separate in the point A [5].

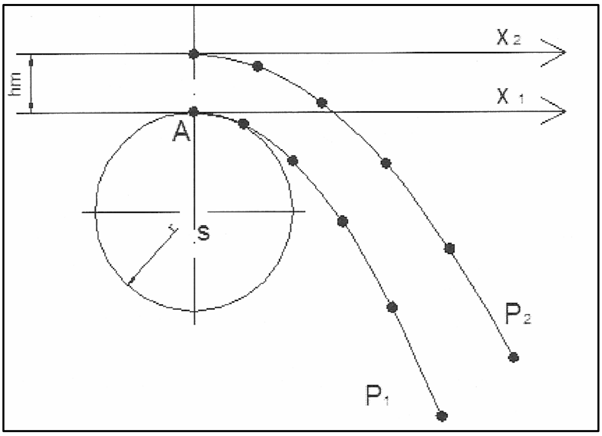

Fig. 2. Construction of the parable for the dump station. Source: [6]

Coordinates of the parable P1 are calculated by [6]:

$$x_n = n.v.\Delta t \qquad (4)$$
$$y_n = \frac{g}{2}(n.\Delta t)^2 \qquad (5)$$

where: n – number of parable points, v – speed of the bottom part of the conveyed material [m.s^{-1}], Δt – selected time interval [s], g - acceleration of gravity [m.s^{-2}]

x_{11} = 1 . 2 . 0,2 = 0,4 m $\quad$ y_{11} = 4,905 . $(1.0,2)^2$ = 0,1962 m (6)
x_{12} = 2 . 2 . 0,2 = 0,8 m $\quad$ y_{12} = 4,905 . $(2.0,2)^2$ = 0,7848 m (7)
x_{13} = 3 . 2 . 0,2= 1,2 m $\quad$ y_{13} = 4,905 . $(3.0,2)^2$ = 1,7658 m (8)
x_{14} = 4 . 2 . 0,2 = 1,6 m $\quad$ y_{14} = 4,905 . $(4.0,2)^2$ = 3,1392 m (9)
x_{15} = 5 . 2 . 0,2= 2 m $\quad$ y_{15} = 4,905 . $(5.0,2)^2$ = 4,905 m (10)

The height of the material layer on the conveyor belt is calculated by:

$$h_m = \frac{3.s_{tab}}{2.b_v} = \frac{3.0,013}{2.0,72} = 0,0271\ m \qquad (11)$$

$$b_v = 0,9.B = 0,9.800 = 720\ mm \qquad (12)$$

The speed of the particle for the top parable is calculated by:

$$v_h = v.\frac{D_b+h_m}{D_b} = 2.\frac{0,315+0,0271}{0,315} = 2,1721\ m.s^{-1} \qquad (13)$$

The coordinates of the parable P2 are calculated according to [6]:

$$x_n = n.v_h.\Delta t \qquad (14)$$
$$y_n = \frac{g}{2}(n.\Delta t)^2 \qquad (15)$$

Where: n– number of points of the parable, v_h – speed of the top part of the conveyed material [m.s^{-1}], Δt – selected time interval [s], g – acceleration of gravity [m.s^{-2}]

x_{21} = 1 . 2,1721.0,2 = 0,4344 m $\quad$ y_{11} = 4,905 . $(1.0,2)^2$ = 0,1962 m (16)
x_{22} = 2 . 2,1721.0,2 = 0,8688 m $\quad$ y_{12} = 4,905 . $(2.0,2)^2$ = 0,7848 m (17)
x_{23} = 3 .2,1721.0,2 = 1,3033 m $\quad$ y_{13} = 4,905 . $(3.0,2)^2$ = 1,7658 m (18)
x_{24} = 4 . 2,1721.0,2 = 1,7377 m $\quad$ y_{14} = 4,905 . $(4.0,2)^2$ = 3,1392 m (19)
x_{25} = 5 . 2,1721.0,2 = 2,1721 m $\quad$ y_{15} = 4,905 . $(5.0,2)^2$ = 4,905 m (20)

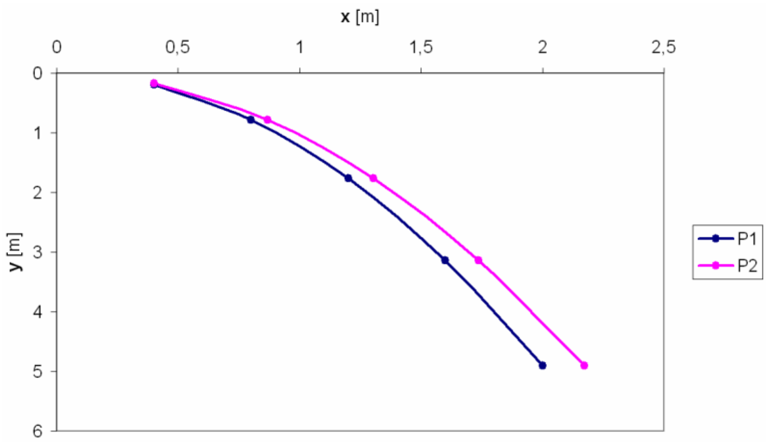

Fig. 3. The parable of the discharge station**.** Source: Authors

5 Conclusion

The realized case study analysed the existing solutions of variable belt conveyors and their advantages. It analyses their constructional solutions and options of their application by specific conditions, such as flexible route/trajectory change, elimination of inter-operation manipulation with the material, environmentally friendly operation with increasing transport performance requirements. The case study and its design part are based on the previous realized conceptual solution of variable pipe conveyor. The design of material conveying by the conceptual solution of variable pipe conveyor is calculated on the modelled situation of fly ash transport to the landfill.

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