PRESENT THEORETICAL ASPECTS, TESTS AND PROPOSALS FOR FLOW CALCULATION ON ROLLER SLANT BELT CONVEYORS

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Abstract: *The paper contains a theoretical analysis and a series of experiments on the factors that the performance of the slant belt conveyors depend on, as well as experimentally verified suggestions for improving the performance of these machines.*

Keywords: *belt, seating, conveyor, inclination*

1. INTRODUCTION

Roller-based belt conveyors for granular and powder materials are used in all fields and rank first in terms of frequency of use, compared to other types of conveyors. For this reason, when the term conveyor is used without any other mention, its implied meaning is that of roller belt. This type of conveyor is the main means of conveyance, most commonly used in all fields of activity, and is superseded by other types of transportation devices only for inclinations of over 18 °...22 °. Using them becomes economical if the minimum flow rate is at least 100...300 t/h and the operation time is at least 5000 hours/year.

Thus, in the case of a 800...1600 mm wide belt, it is recommended that size of the ore pieces should not exceed 150...300 mm. If the pieces of ore are larger, intense wear will affect the belt.

The above-mentioned conveyors can be divided into two categories:

- half-stationary conveyors
- stationary conveyors

Stationary conveyors are used for preparation works or secondary works within the perimeters of exploitation sectors with a lifespan of up to 1...2 years, and they usually change their length periodically its length as the working faces advance.

Stationary conveyors are horizontal or inclined, they have long life spans (over 2...3 years), a solid and rigid construction, and conveying speeds of 2...4.5 m / s.

2. PRESENT FLOW CALCULATION METHOD FOR A ROLLER BELT SLANT CONVEYOR

On this type of belt the material being transported could be, theoretically, loaded up to the edge of the belt so that the section view will show an equilateral triangle (see the dashed line shown in Figure 1) where the angle between the slanted sides and the horizontal side is equal to the angle of repose in motion ρ_m. There is, in this case, the possibility for the material to flow over the edge of the belt, which is why, in the actual practice, the material can only be loaded on a length equal to $0,8 \cdot B$ and in such a quantity that the section resulted will correspond to the hatched triangle shown in Figure 1, whose sides are slanted against the horizontal plane by the angle:

$$\rho_1 = 0,5 \cdot \rho_m$$

or (if the angle of repose at rest is not known) approximately:

$$\rho_1 = 0,35 \cdot \rho$$

$$\rho_1 = 0,35 \cdot 26,8 = 9,38^0$$

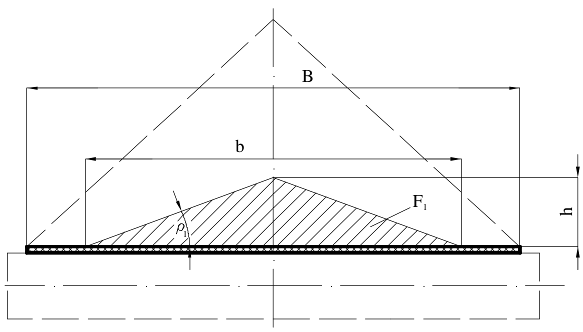

Fig. 1. Flat belt loading

The values of ρ and ρ_m angles are given in Table 1.

For sand, the material that will be used in the experiments, the angle of repose at rest is ρ = 26.8 °

Since the angle of repose in motion could not be determined experimentally, the following equation will be used in order to determine its value:

$$0,35 \cdot \rho = 0,5 \cdot \rho_m$$

based on the relations used for ρ_1 , defined above.

Result: $\rho_m = \dfrac{0,35}{0,5} \rho = \dfrac{0,35}{0,5} \cdot 26,8 = 18,76^0$

Aria of triangular section of the layer of material is:

$$A = \frac{b \cdot h}{2} = 0{,}16 \cdot B^2 \cdot tg\rho_1 \ \mathrm{m}^2$$

where $b = 0{,}8 \cdot B$

and $h = 0{,}5 \cdot b \cdot tg\rho_1 = 0{,}4 \cdot B \cdot tg\rho_1$

Table 1

Material	*Volumetric Weight* γ t/m^3	*Angle of Repose*		*Coefficient of friction at rest*		
		ρ	ρ_m	*steel*	*wood*	*rubber*
Sand	1,60...1,80	26,8°	18,76°	0,56...1	0,7	-

The weight of the material placed on a linear meter of belt:

$$q = A \cdot 1 \cdot \gamma = 0{,}16 \cdot B^2 \cdot \gamma \cdot tg\rho_1 \quad \mathrm{t/m} \tag{1}$$

$$q = 160 \cdot B^2 \cdot \gamma \cdot tg\rho_1 \quad \mathrm{kg/m} \tag{2}$$

where:

γ = the volumetric weight of the material, given in t/m^3

$$\gamma = 1{,}60...1{,}80 \ \ t/m^3$$

The result of the determinations was:

$$\gamma = 1{,}536 \ \mathrm{t/m^3} = 1536 \ \mathrm{kg/m^3}$$

B = the belt width of the installation on which the experiments are performed, given in m;

$$B = 0{,}2 \ m$$

The productivity (flow) of a flat belt conveyor is determined based on the relation:

$$Q = 3{,}6 \cdot q \cdot v = 576 \cdot B^2 \cdot \gamma \cdot v \cdot tg\rho_1 \quad \mathrm{t/h} \tag{3}$$

Replacing all the values in the relation (3), there results:

$$Q = 576 \cdot 0{,}2^2 \cdot 1{,}536 \cdot 0{,}1652 \cdot v \quad \mathrm{t/h}$$

$$Q = 5{,}846 \cdot v \quad \mathrm{t/h} \tag{4}$$

where: v = the speed of the belt, given in m/s,

When calculating the conveyor's productivity there will be taken into account a β proper-value coefficient, which depends on the slope of the conveyor, and is shown, for sand, in Table 2.

Table 2

Slope of the conveyor (°)	β	Slope of the conveyor (°)	β
2°	1	14°	0,98
5°	0,98	18°	0,85
10°	0,95	22°	0,76

The result: $Q = \beta \cdot 5{,}846 \cdot v$ t/h (5)

Therefore, when performing the experiments, there will be used and checked the relationship (5) if the conveyor operates with a slope angle $\beta > 2°$.

3. DESCRIPTION OF THE CONVEYING SYSTEM USED IN THE EXPERIMENTS

For experimental purposes there is used a belt conveying system as presented schematically in Figure 2. This system can both incline at an angle between 0° and 45° against the horizontal plane and work at varying belt speeds between 0 and 1 m/sec.

The experimental system is equipped with all the elements of a flexible traction industrial conveying system, the most important of which are specified in Figure 2 [1].

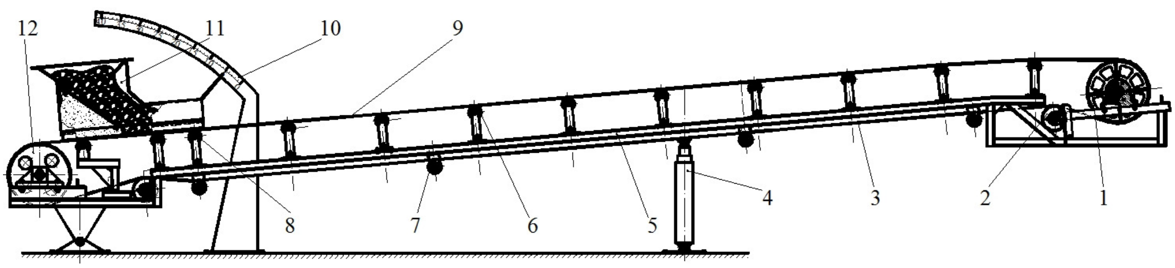

Fig. 2. Drawing of the installation required for experiments

1 – drive drum; **2** – actuating roll; **3** - the lower branch of the belt; **4** - lifting device; **5** – conveyor's bed;

6 – idle roller supporting the upper branch of the belt; **7 –** idle roller supporting the lower branch of the belt; **8** – roller bed; **9** - the upper branch of the belt; **10** - graduated sector; **11** - feeding device; **12** - Return drum.

4. PERFORMING THE TESTS

The purpose of the experiments consists in:

- determining the conveyor's flow rates for various values of the β coefficient at a certain travelling speed of the belt, using the relation (5).
- determining the angles of slope for the traction and transport body (the belt), both at rest and in motion, at which the transported material begins to slide, causing the transport capacity (the flow rate of the conveyor) to decrease.
- verifying the applicability of the relationship (5)
- proposing original solutions to increase the flow of the transported material with the conveyor set at the upper limit of inclination (when the material begins to slide).

4.1 Determining the experimental system's flow rates at various travelling speeds of the belt for slant conveyors

The flow rate of the experimental system at various β values and speeds of the flexible traction body is calculated based on the relation (5) in its final form [2], [3]:

$$Q_t = \beta \cdot 5{,}846 \cdot v \qquad \text{t/h} \tag{6}$$

where: β is a coefficient depending on the conveyor's slope (the slope of the flexible transport body, expressed in degrees), and whose values are shown Table 3.

The flow rates calculated using the relation (5), as well as the rates determined experimentally are shown in Table 3, and the graphs of the function $Q = f(v)$, both the theoretical and the experimental one, for two values of the angle of slope β, are shown in Figure 3. a and b. In order to be able to use the experimental system, the relation for Q, as expressed in t/h, is transformed so that the Q is expressed in kg/min [4].

We acted in this manner because of the limited amount of sand available to us.

$$Q_t = \beta \cdot 5{,}846 \cdot \frac{1000}{60} \cdot v = \beta \cdot 97{,}43 \cdot v \ \text{kg/min} \tag{7}$$

Table 3

v m/s	0,1	0,2	0,3	0,4	0,5
Conveyor slope	5^0				
β_1	0,98				
Q_t kg/min	9,55	19,09	28,65	38,19	47,75
Q_{exp} kg/min	8,5	16,8	25,3	33,6	41,6
Conveyor slope	22^0				
β_2	0,76				
Q_t kg/min	7,40	14,80	22,21	29,62	37,03
Q_{exp} kg/min	6,60	13,10	19,60	26,10	32,30

As can be noticed looking at Table 3, also on conveyors with the transport body set at certain slopes, the experimentally determined values for the conveyor's flow, Q_{exp}, are lower than those calculated using the relation (5) for the Q_t flow.

This can be noticed also looking at the variance graphs of the functions $Q_t=f(v)$ and $Q_{exp}=f(v)$, for two β values ($\beta 1$ and $\beta 2$), corresponding to the two inclinations of the conveyor (5° and 22° respectively) from Figure 3. a , b.

The difference between the experimentally determined flow value, Q_{exp}, and the theoretically determined value, Q_t, is expressed also as a percentage in Table 3.

It is worthy of note that, when the conveyor's inclination is higher than 22°, therefore $\beta=0.76$, the material loaded on the traction and transport body starts to slide, the flow decreases below the acceptable limit and therefore the conveyor can no longer be used.

However, this finding refers only to the pair of materials (i.e. sand grains and polyvinyl chloride-impregnated cloth belt) used during the experiments presented.

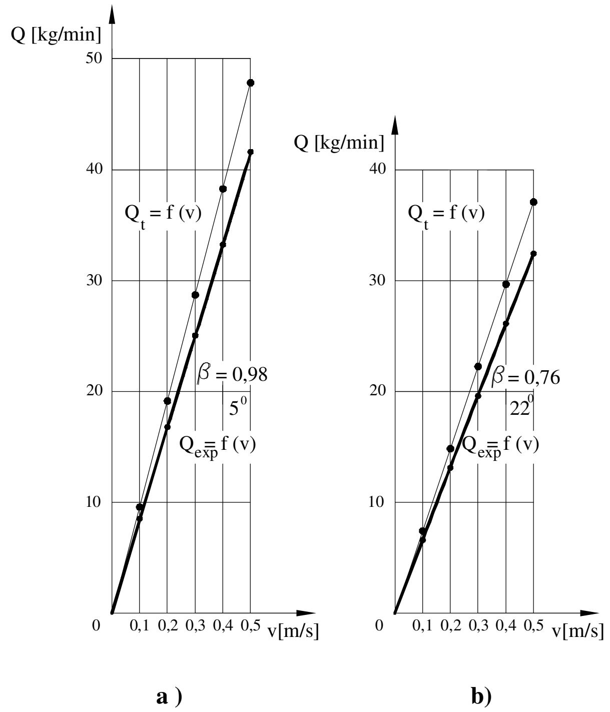

Figure 3. The graphs of the functions $Q_t = f(v)$ and $Q_{exp} = f(v)$ for slopes of 5° and 22° respectively

4.2 Verifying the applicability of the relation (5) for the flow of a slant conveyor with a roller flexible transmission body

As can be seen looking at Table 3, the flow values calculated based on the relation (5) are, for the slant belt too, higher than the values determined experimentally, by a percentage whose value, as in the case studied before, grows as the speed of the flexible transport body increases, and ranges between 12.3% and 14.8% for β=0.98 and between 12.1 and 14.6 for β=0.76.

Just as in the case of the horizontal conveying system studied before, this finding leads us to propose, for determining the theoretical flow, only for smooth surface traction and transport bodies, a relationship of the form:

$$Q_t = \frac{\beta}{\alpha_v} \cdot 5{,}846 \cdot v \quad \text{t/H} \qquad (8)$$

- where: α_v is an improper value coefficient of velocity, with estimated values in accordance with the values given in Table 4. It is specific to the material used during the experiments.

Table 4

v m/s	0,1	0,2	0,3	0,4	0,5
β_1	0,98				
Q_t kg/min	9,55	19,09	28,65	38,19	47,75
Q_{exp} kg/min	8,50	16,80	25,30	33,60	41,60
Q_t/Q_{exp} [α_{v1}]	1,123	1,135	1,132	1,136	1,148
%	12,3	13,5	13,2	13,6	14,8
β_2	0,76				
Q_t kg/min	7,40	14,80	22,21	29,62	37,03
Q_{exp} kg/min	6,60	13,10	19,60	26,10	32,30
Q_t/Q_{exp} [α_{v2}]	1,121	1,129	1,133	1,135	1,146
%	12,1	12,9	13,3	13,5	14,6

5. CONCLUSIONS

Following the experiments performed on the conveying system presented at section 3, we have come to the following conclusion:

- the actual flow of a flexible, plane traction and transport body slant conveyor is not proportional to the travelling speed of the transport body, according to the relations (6) and (7), but depends, as in the case of the horizontal conveyors, on an improper-value coefficient of velocity, α_v, whose value increases as the travelling speed of the transport body increases.

In accordance with Table 4 and the graphs shown in Figure 3, resulting from the experiments performed for two values of the angle of slope β, we are propsing a relationship of the form (8), which reflects more accurately the flow variation according to the speed of the transport body.

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