UDC 622.647.2:621.867.2 DOI: https://doi.org/10.15407/geotm2021.158.070

DETERMINING OF LIMITING ANGLE OF INCLINATION OF BELT CONVEYOR WITH PARTITIONS

[1]Kiriia R.V., [1]Monastyrskyi V.F., [1]Mishchenko T.F., [1]Mostovyi B.I.

[1]*Institute of Geotechnical Mechanics named by N. Poljakov of NAS of Ukraine*

ВИЗНАЧЕННЯ ГРАНИЧНОГО КУТА НАХИЛУ СТРІЧКОВОГО КОНВЕЄРА З ПЕРЕГОРОДКАМИ

[1]Кірія Р.В., [1]Монастирський В.Ф., [1]Міщенко Т.Ф., [1]Мостовий Б.І.

[1]*Інститут геотехнічної механіки ім. М.С. Полякова НАН України*

ОПРЕДЕЛЕНИЕ ПРЕДЕЛЬНОГО УГЛА НАКЛОНА ЛЕНТОЧНОГО КОНВЕЙЕРА С ПЕРЕГОРОДКАМИ

[1]Кирия Р.В., [1]Монастырский В.Ф., [1]Мищенко Т.Ф., [1]Мостовой Б.И.

[1]*Институт геотехнической механики им. Н.С. Полякова НАН Украины*

Abstract. Currently, due to the the deepening of open at extraction of minerals, steeply inclined conveyors are widely used. One of the common types of steeply inclined belt conveyors is the belt conveyors with partitions. This type of conveyor is mainly used for small-sized loads. Recently, however, they began to be used for bulk loads, including, in addition to small-sized loads, also individual pieces, the maximum size of which is more than 150 mm. According to literary sources, the limiting angle of inclination of the belt conveyor with partitions is in the range from 35º to 60º. However, until now, there are no studies that determine the dependence of the values of the limiting angle of inclination of the belt conveyor with partitions on the parameters of the conveyor, the size of the partitions and the properties of the transported load. In this work, based on the laws of the statics of a granular medium, the limiting angle of inclination of the belt conveyor with partitions is determined depending on the linear load of the transported bulk load, the height of the partition and the distance between them, as well as the slope angle of the bulk load. Two cases were considered in the work: the case when the bulk load between the partitions covers the entire conveyor belt, and the case when the bulk load covers part of the conveyor belt. As a result, it was found that in the first case, the tangent of the limiting angle of inclination of the belt conveyor with partitions decreases linearly with increasing linear load, and in the second case, when the bulk load does not completely cover the conveyor belt, the tangent of the limiting angle of inclination of the belt conveyor decreases with increasing linear load according to the hyperbolic law. At the same time, with an increase in the height of the partition, the limiting angle of inclination of the belt conveyor increases. In addition, the dependences of the volumetric productivity of a belt conveyor with partitions on the limiting angle of inclination of the conveyor were obtained. At the same time, with an increase in the limiting angle of inclination of the belt conveyor, the productivity of the conveyor decreases, and with an increase in the height of the partition, it increases. The research results can be when at designing belt conveyor with partitions on the belt, for transporting bulk loads.

Keywords. Belt conveyors, bulk load, partitions on the belt, limiting angle of inclination.

Currently, steeply inclined conveyors with partitions are widely used in Ukraine and abroad. This type of conveyor is used both for small-sizes loads and for bulk loads, including individual large pieces of load, the maximum size of which is more than 150 mm [1].

According to literary sources, the limiting angle of inclination of the conveyor with partitions is in the range from 35º to 60º [1, 2, 3, 4]. However, until now, there are no studies that determine the dependence of the value of the limiting angle of inclination of the belt conveyor with partitions on the parameters of the conveyor, the size of the partitions and the properties of the transported bulk load.

In this work, based on the laws of the statics of a granular medium, the limiting angle of inclination of a belt conveyor with partitions is determined depending on the linear load of the transported bulk load, the height and distance between the partitions, as well as on the slope of the bulk load.

Let's consider the limiting balance of bulk load between the partitions and the belt conveyor with an angle of inclination to the horizon equal to α (Fig. 1, *a*, *b*).

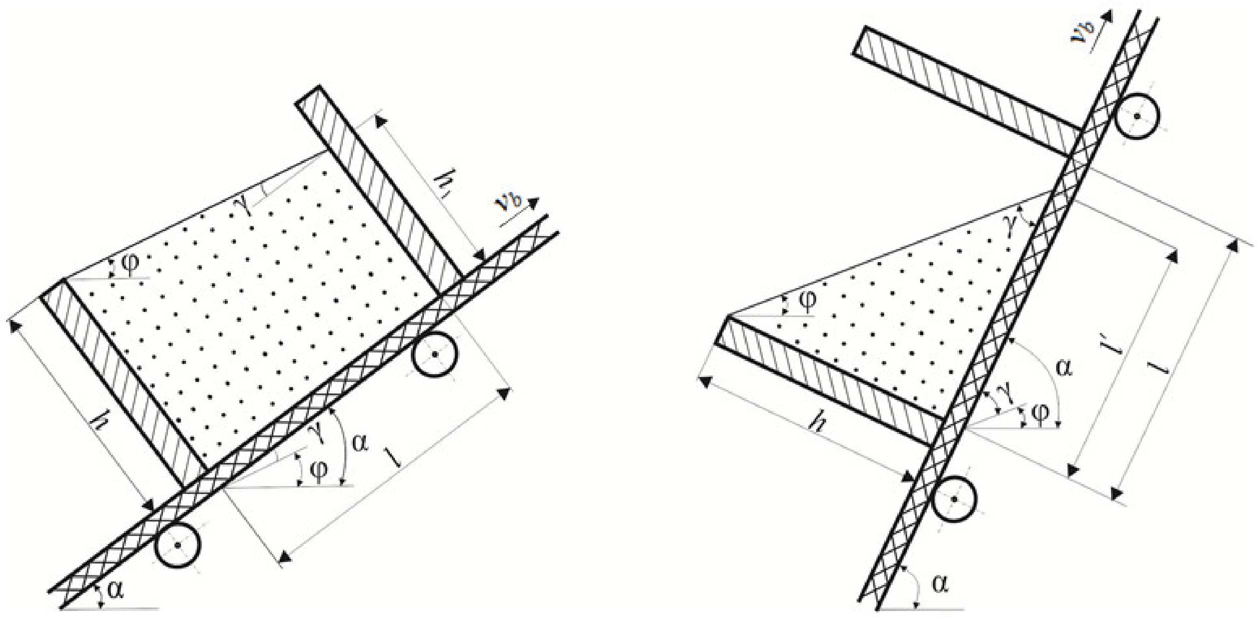


Figure 1 – Calculation schemes for the balance of bulk load on the belt conveyor with partitions

Let's consider two cases when the bulk load between the partitions covers the entire conveyor belt (see Fig. 1,*a*), and the case when the bulk load between the partitions covers part of the conveyor belt (see Fig. 1,*b*). In this case, the width between the sides of the conveyor is *B* (m), the distance between the partitions is *l* (m), the height of the partitions is *h* (m) and the speed of the conveyor belt is v_b (m/s).

From Figures 1,*a*,*b* it follows that the limiting angle of inclination of the belt conveyor with partitions is determined by the formula

$$\alpha = \beta + \varphi, \tag{1}$$

where β - is the angle between the free surface of the bulk load lying between the partitions and the surface of the conveyor belt, °C; φ - is the limiting angle between the free surface of the bulk load and the horizontal plane, i.e. bulk load slope angle, °C.

From formula (1) it follows that the limiting angle of inclination of the belt conveyor with partitions is greater than or equal to the slope angle of the bulk load, i.e. $\alpha \geq \varphi$.

In the first case, when the bulk load between the partitions completely covers the conveyor belt (see Fig. 1,*a*), the volume of the bulk load is determined by the formula

$$V_1 = S_1 B \ (\text{m}^3), \tag{2}$$

where S_1 -is the area of the side wall between the partition filled with bulk load, (m^2).

According to Figure 1,*a* the area S_1 is determined by the formula

$$S_1 = \frac{h + h_1}{2} l, \tag{3}$$

where h_1 - is the height of the layer of bulk load near the front partition, m.

From Figure 1, *a* we have

$$h_1 = h - l \cdot \text{tg}\beta,$$

or with taking into account (1)

$$h_1 = h - l \cdot \text{tg}(\alpha - \varphi). \tag{4}$$

By substituting (3) into (2), and with taking into account (4), after the transformation, we obtain

$$V_1 = Bl\left[h - \frac{l}{2} \cdot \text{tg}(\alpha - \varphi) \right]. \tag{5}$$

The weight of the bulk load located between the partitions, in the first case, is determined by the formula

$$P_1 = \gamma V_1. \tag{6}$$

where γ - is the specific gravity of the transported bulk load, N/m^3.

The specific gravity γ is determined by the formula

$$\gamma = 1000 \rho g, \tag{7}$$

where ρ - is the specific density of bulk load, t/m^3; g - is acceleration of gravity, m/s^2.

The average linear load of bulk load on a conveyor belt with partitions is determined by the formula

$$q = \frac{P_1}{l} \ (\text{N/m}). \tag{8}$$

By substituting (6) into (8), and with taking into account (5), after transformation, we obtain the average linear load in the first case equal to

$$q = \gamma B[h - \frac{l}{2}\mathrm{tg}(\alpha - \varphi)]. \tag{9}$$

From Fig. 1,*a* it follows that formula (9) is valid under the condition

$$h \geq l \cdot \mathrm{tg}\beta = l \cdot \mathrm{tg}(\alpha - \varphi). \tag{10}$$

From equality (9), having determined the expression $l \cdot \mathrm{tg}(\alpha - \varphi)$ and by substituting it into inequality (10), we obtain

$$q \geq \frac{\gamma h B}{2}. \tag{11}$$

Therefore, in the first case of the limiting angle of inclination of the belt conveyor with partitions, inequality (11) must be satisfied, i.e. the average linear load should be more than half of the maximum possible load of the belt conveyor with partitions in a horizontal state.

Let us determine the angle α from equality (10), as a result, we obtain the limiting angle of inclination of the belt conveyor with partitions in the first case equal to

$$\alpha = \mathrm{arctg}\left(\frac{2h}{l} - \frac{2q}{\gamma l B}\right) + \varphi. \tag{12}$$

Equality (12) has a physical meaning under the condition

$$\frac{2h}{l} - \frac{2q}{\gamma l B} \geq 0.$$

The last inequality implies

$$q \leq \gamma h B. \tag{13}$$

Therefore, according to inequalities (11) and (13), in the first case, the limiting angle of inclination of the belt conveyor with partitions is determined by formula (12), provided that the linear load q is within the limits

$$\frac{\gamma h B}{2} \leq q \leq \gamma h B. \tag{14}$$

Let us consider the second case, when the bulk load in the limiting state, located between the partitions, does not completely cover the conveyor belt (see Fig. 1,*b*). In this case, the bulk load covers a segment of the tape equal to l' (m), which is less than the distance between the partitions, i.e.

$$l' \le l. \tag{15}$$

From Fig. 1,*b* it follows

$$l' = \frac{h}{\mathrm{tg}\beta} = \frac{h}{\mathrm{tg}(\alpha - \varphi)}. \tag{16}$$

By substituting l' from (16) into inequality (15), as a result, we obtain the inequality that takes place in the second case

$$h \le l \cdot \mathrm{tg}(\alpha - \varphi). \tag{17}$$

The area of the side wall filled with bulk load and lying between the partitions S_2, according to Figure 1,*b*, and with taking into account (16), is determined by the formula

$$S_2 = \frac{hl'}{2} = \frac{h^2}{2\mathrm{tg}(\alpha - \varphi)}. \tag{18}$$

The volume of bulk load located between the partitions, in the second case, is determined by the formula

$$V_2 = S_2 B \text{ (m}^3\text{)}. \tag{19}$$

The weight of the bulk load between the partitions is

$$P_2 = \gamma V_2 \text{ (H)}. \tag{20}$$

The average linear load on a conveyor belt with partitions in the second case is determined by the formula

$$q = \frac{P_2}{l}. \tag{21}$$

By substituting (19) into (20), and the resulted value P_2 into (21), and with taking into account (18), after the transformation, we obtain

$$q = \frac{\gamma h^2 B}{2l \cdot \mathrm{tg}(\alpha - \varphi)}. \tag{22}$$

From equality (22), having determined α, as a result, we obtain the limiting angle of inclination of the belt conveyor with partitions in the case of incomplete coverage of a section of the belt between the partitions with a bulk load:

$$\alpha = \operatorname{arctg}\left(\frac{\gamma h^2 B}{2ql}\right) + \varphi. \tag{23}$$

Formula (23), as shown earlier, has a physical meaning under condition (17).

From formula (22), having determined $\operatorname{tg}(\alpha - \varphi)$ and substituted the obtained value into inequality (17), we obtain

$$q \le \frac{\gamma h B}{2}. \tag{24}$$

Consequently, formula (23) has a physical meaning under the condition

$$0 \le q \le \frac{\gamma h B}{2}. \tag{25}$$

Finally, the limiting angle of inclination of the belt conveyor with partitions according to formulas (12) and (23), and with taking into account (14) and (25), is determined by the formulas

$$\alpha = \begin{cases} \operatorname{arctg}\left(\dfrac{\gamma h^2 B}{2ql}\right) + \varphi & \text{at } 0 \le q \le \dfrac{\gamma h B}{2}; \\ \operatorname{arctg}\left(\dfrac{2h}{l} - \dfrac{2q}{\gamma l B}\right) + \varphi & \text{at } \dfrac{\gamma h B}{2} \le q \le \gamma h B. \end{cases} \tag{26}$$

Let us now determine the filling factor of the belt with bulk load, equal to the ratio of the volume of bulk load lying between the partitions to the maximum volume of space between the partitions of the belt conveyor with partitions

$$\varepsilon = \frac{V}{V_{\max}}, \tag{27}$$

where V is the volume of bulk load located between the partitions, m^3; $V_{\max}$ is maximum volume of space between partitions, m^3.

The volume of bulk load located between the partitions, both in the first and in the second case, can be expressed in terms of the average linear load q by the formula

$$V = ql\,. \tag{28}$$

The maximum volume of bulk load that can be between the partitions is determined by the formula

$$V_{\max} = \gamma lhB\,. \tag{29}$$

By substituting formulas (28) and (29) into (27), we obtain the value of the filling factor of the belt conveyor with partitions, both in the first and in the second case, equal to

$$\varepsilon = \frac{q}{\gamma hB}\,. \tag{30}$$

By substituting in formula (30) instead q its expression according to formulas (9) and (22), we obtain the value of the filling factor ε

for the first case

$$\varepsilon = 1 - \frac{l}{2h}\mathrm{tg}(\alpha - \varphi)\,; \tag{31}$$

for the second case

$$\varepsilon = \frac{h}{2l \cdot \mathrm{tg}(\alpha - \varphi)}\,. \tag{32}$$

From formula (30) it follows that at low values of the linear load $q < 0.5\gamma hB$, i.e. at large values of the filling factor of the belt $\varepsilon > 0.5$, the limiting angle of inclination of the belt conveyor α takes on large values, close to 90°. And for large values $0.5\gamma hB < q < \gamma hB$, i.e. at small values $\varepsilon < 0.5$, the limiting angle of inclination of the conveyor α takes small values.

By substituting the value $q = 0.5\gamma hB$ into formulas (26) and (30), we obtain the limiting value of the angle of inclination of the belt conveyor with partitions α, at which the filling factor of the belt takes the optimal value ε = 0.5

$$\alpha_0 = \mathrm{arctg}\left(\frac{h}{l}\right) + \varphi\,. \tag{33}$$

Consequently, the limiting angle of inclination of the belt conveyor with partitions, at which the filling factor is optimal, is equal to the sum of the angle between the diagonal plane of the cell between the partitions with the plane of the conveyor belt and the slope angle of the bulk load (Fig. 2).

In Table 1, values of the limiting angle of inclination α_0 are given for various values of the distance between partitions l and the height of the partitions h.

Table 1 – Limiting angles of inclination of the belt conveyor with partitions α_0 (°C) at ε = 0.5 and φ = 20º

Height partitions h (m)	Distance between partitions l (m)							
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.1	38.4	34.0	31.3	29.5	28.1	28.1	26.3	28.7
0.2	53.7	46.6	41.8	38.4	35.9	34.0	32.5	31.3
0.3	65.0	56.9	51.0	46.6	43.2	40.6	38.4	36.7
0.4	73.1	65.0	58.7	53.7	49.7	46.6	44.0	41.8
0.5	79.0	71.3	65.0	59.8	55.5	52.0	49.1	46.6

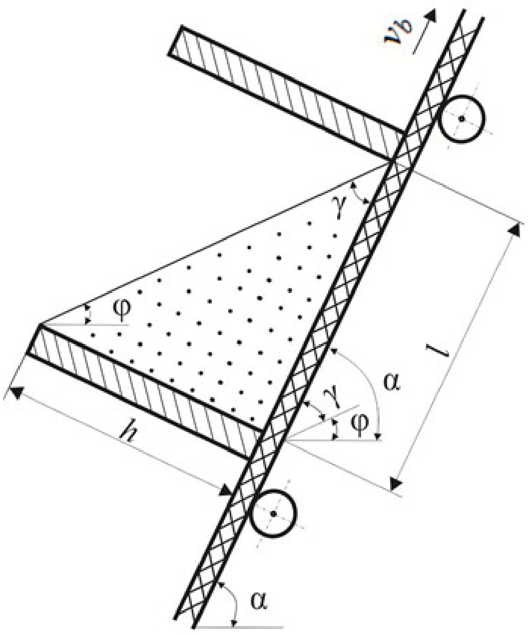


Figure 2 – Calculation schemes of the balance of bulk load in the case of the optimal filling factor the cell with bulk load (ε = 0.5) on a belt conveyor with partitions

The mass productivity of the belt conveyor with partitions according to [5] is determined by the formula:

$$Q = \frac{3.6}{g} q v_b \text{ (t/h)}.$$

Then the volumetric productivity is determined by the formula

$$Q = \frac{3.6}{\rho g} q v_b \text{ (m}^3\text{/h)}. \quad (34)$$

Formula (34) with taking into account (7) can be represented as

$$Q = 3.6 \cdot 10^3 \frac{q v_b}{\gamma}. \tag{35}$$

By substituting into the last formula q from expression (22), after the transformation, we obtain the volumetric productivity of the belt conveyor with partitions in the case of incomplete filling of the belt between the partitions with a bulk load (second case), equal to

$$Q = 3.6 \cdot 10^3 \cdot v_b \frac{h^2 B}{2l \cdot \mathrm{tg}(\alpha - \varphi)}. \tag{36}$$

Formula (36), according to inequality (17) and inequality $\alpha \geq \varphi$, is valid provided

$$\varphi \leq \alpha \leq \mathrm{arctg}\left(\frac{h}{l}\right) + \varphi. \tag{37}$$

By substituting into formula (35) q from expression (9), after transformation we obtain the volumetric productivity of the belt conveyor with partitions in the case of complete filling of the belt between the partitions with a bulk load (the first case), equal to

$$Q = 3.6 \cdot 10^3 \cdot v_b B \cdot \left[h - \frac{l}{2} \mathrm{tg}(\alpha - \varphi)\right]. \tag{38}$$

Formula (38) according to inequality (10) is valid under the condition

$$\mathrm{arctg}\left(\frac{h}{l}\right) + \varphi \leq \alpha \leq 90^\circ. \tag{39}$$

The final volumetric productivity of the belt conveyor with partitions, depending on the limiting angle of inclination, is determined by the formulas:

$$Q = \begin{cases} 3.6 \cdot 10^3 \dfrac{v_b h^2 B}{2l \cdot \mathrm{tg}(\alpha - \varphi)} & \text{at } \varphi \leq \alpha \leq \mathrm{arctg}\left(\dfrac{h}{l}\right) + \varphi; \\ 3.6 \cdot 10^3 \, v_b B \left[h - \dfrac{l}{2} \mathrm{tg}(\alpha - \varphi)\right] & \text{at } \mathrm{arctg}\left(\dfrac{h}{l}\right) + \varphi \leq \alpha \leq 90^\circ. \end{cases} \tag{40}$$

Formula (40), with taking into account (31) and (32), can be represented as

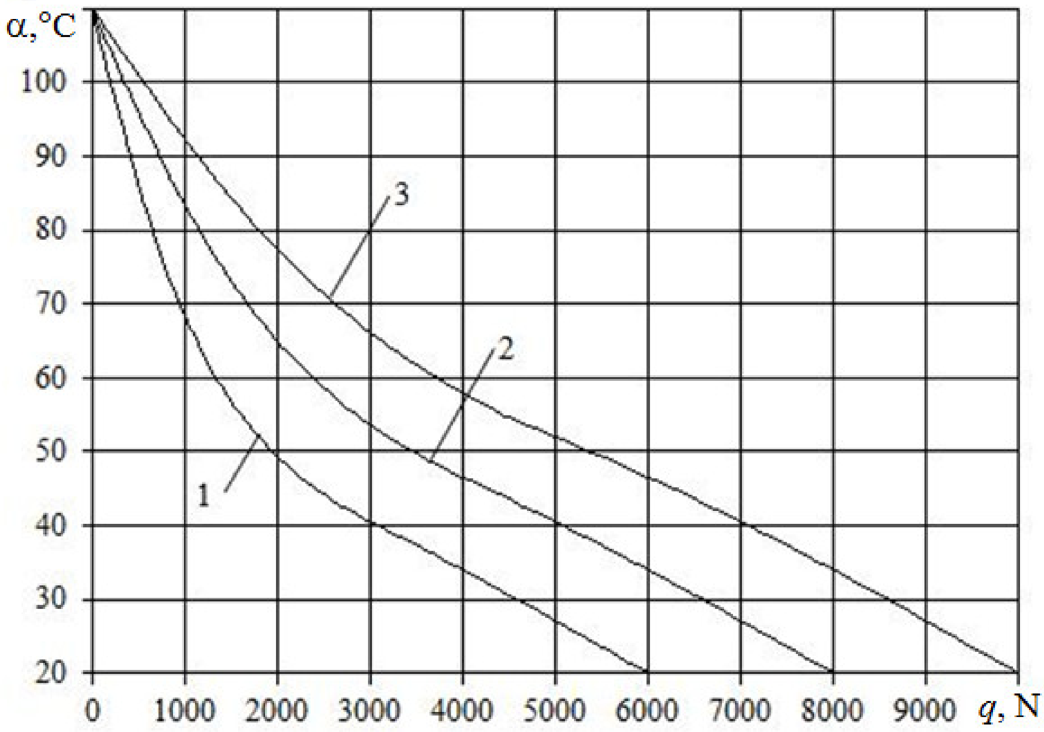
$$Q = 3.6 \cdot 10^3 \, v_b h B \varepsilon. \tag{41}$$

By substituting in (41) the optimal value of the filling factor of the belt ε = 0.5, we obtain the value of the volumetric productivity equal to

$$Q = 1.8 \cdot 10^3\, v_b h B. \tag{42}$$

In figure 3 the graphs of the dependence of the limiting angle of inclination of the belt conveyor with partitions on the linear load q at various values of the height of the partitions h = 0.3 m; 0.4 m; 0.5 m, constructed according to formulas (26) are show. In this case, the slope angle of the bulk load is φ = 20°; the distance between the partitions is l = 0.8 m; the distance between the sides of the conveyor B = 0.8 m; specific gravity of transported bulk load γ = 25000 N/m^3.

In figure 4 the graphs of the dependence of the filling factor with the load of the belt conveyor with partitions ε on the linear load q at various values of the height of the partitions h = 0.3 m; 0.4 m; 0.5 m, constructed according to formula (30) with the same parameter values as in Fig. 3, are show.

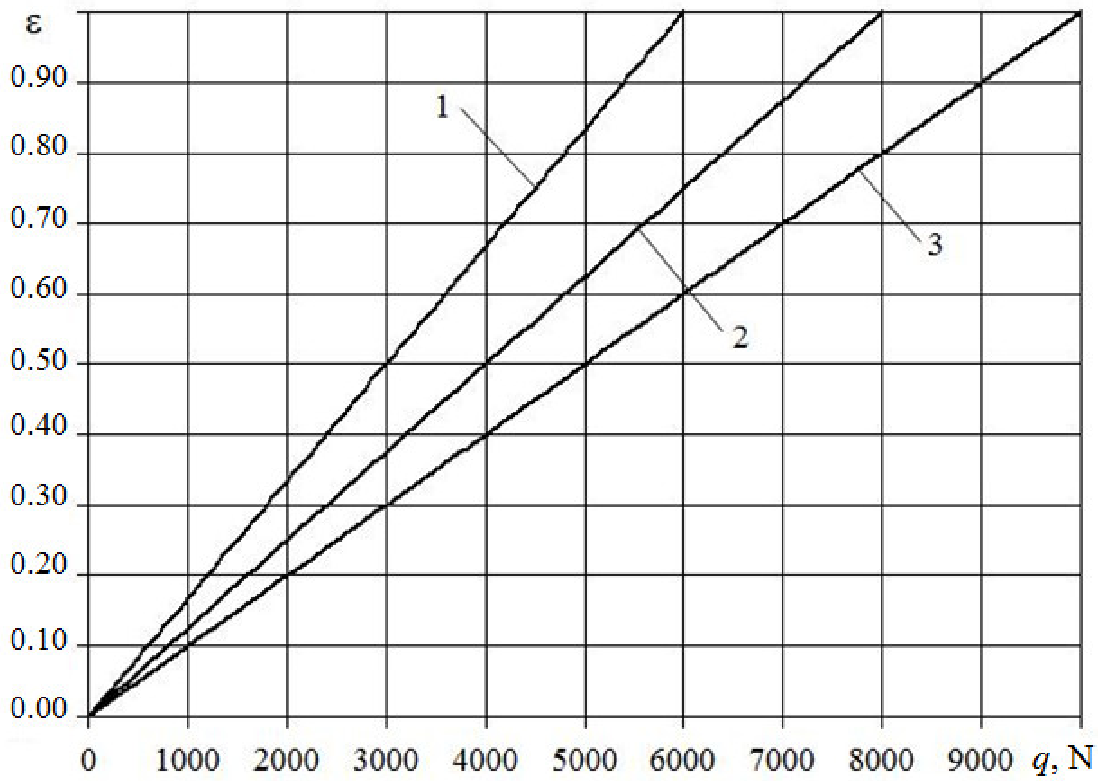


1 – h=0.3 m; 2 – h = 0.4 m; 3 – h = 0.5 m

Figure 3 – Dependence of the limiting angle of inclination of the conveyor with partitions α on the linear load q for different values of the height of the partitions h

From the graphs in Figures 3 and 4, it can be seen that with an increase in the linear load q, the limiting angle of inclination of the belt conveyor with partitions α decreases from 110° to 20°, and the filling factorε increases from 0 to 1.

In this case, with an increase in the height of the partitions h, the limiting angle of inclination of the belt conveyor α and the filling factor of the belt ε increase.



1 – h=0.3 m; 2 – h = 0.4 m; 3 – h = 0.5 m

Figure 4 – Dependence of the filling factor with the load of the belt conveyor with partitions ε from linear load q for different values of partition heights h

In addition, it follows from Figures 3 and 4 that at the optimal filling factor $\varepsilon = 0.5$, the limiting angle of inclination α and, accordingly, the linear load q take the values $\alpha = 40.6°$; $46.6°$; $52°$ and $q = 3000$ N/m; 4000 N/m; 5000 N/m at $h = 0.3$ m; 0.4 m; 0.5 m respectively.

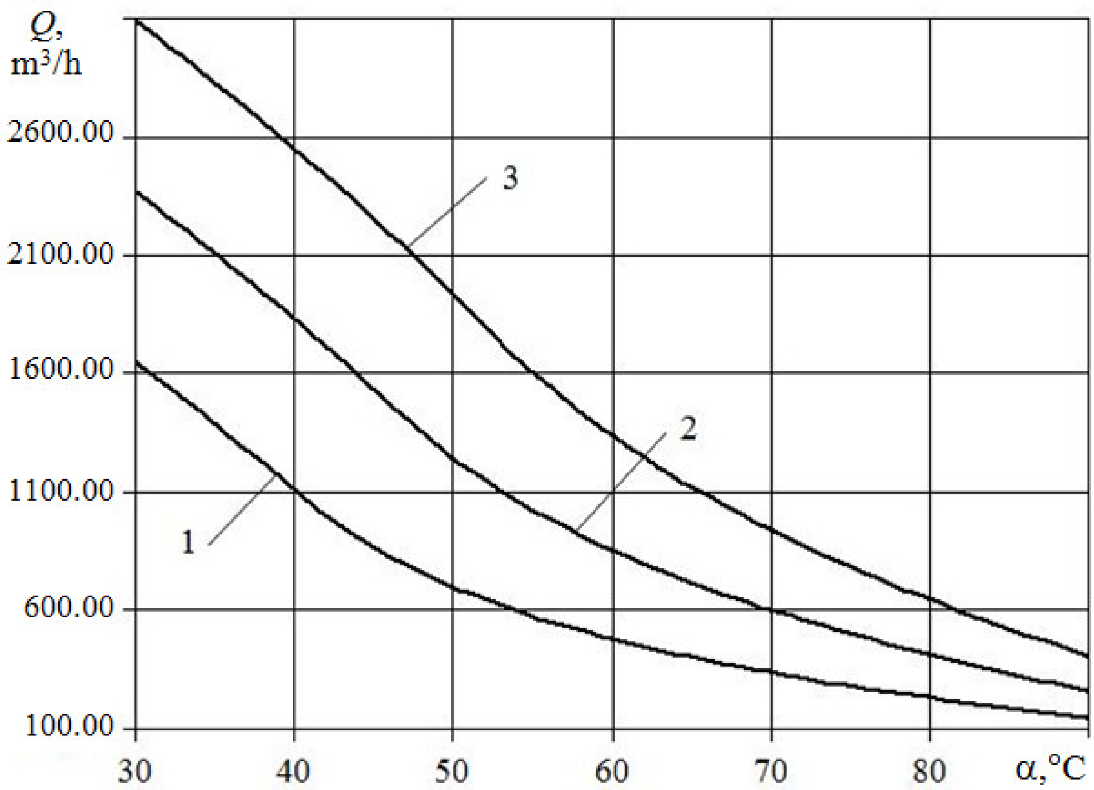
In figure 5 the graphs of the dependence of the volumetric productivity Q of a belt conveyor with partitions on the limiting angle of inclination of the conveyor α at various values of the height of partitions $h = 0.3$ m; 0.4 m; 0.5 m, constructed according to formulas (39) with the same parameter values as in Fig. 3, are show.

Figure 5 shows that with an increase in the limiting angle of inclination α of the belt conveyor with partitions, the volumetric productivity Q decreases, and increases with an increase in the height of the partitions.

At the same time, with the optimal value of the filling factor $\varepsilon = 0.5$, the volumetric capacity takes on the values $Q = 1080$ m^3/h; 1440 m^3/h; 1800 m^3/h at $h =$ 0.3 m; 0.4 m; 0.5 m respectively.

Conclusions

1. Based on the laws of the statics of a granular medium, the limiting angle of inclination of the belt conveyor with partitions is determined depending on the linear load, the height of the partitions and the distance between them, as well as on the slope of the bulk load.



1 – *h* = 0.3 m; 2 – *h* = 0.4 m; 3 – *h* = 0.5 m

Figure 5 – Dependence of the volumetric productivity *Q* of the belt conveyor with partitions from the limiting angle of inclination of the conveyor α

2. On the basis of the obtained dependence, it is established that with an increase in the linear load, the limiting angle of inclination of the belt conveyor with partitions decreases, and increases with an increase in the height of the partitions.

3. The value of the limiting angle of inclination of the belt conveyor with partitions is determined, at which the filling factor takes the optimal value equal to 0.5. In this case, the limiting angle of inclination of the belt conveyor is equal to the sum of the angle between the diagonal plane of the cell between the partitions with the plane of the conveyor belt and the slope angle of the bulk load.

4. The volumetric productivity of the belt conveyor with partitions is determined depending on the limiting angle of inclination of the conveyor. Moreover, the higher is the limiting angle of inclination, the lower is the volumetric productivity of the conveyor.

REFERENCES

1. Galkin, V.I., Dmitriev, V.G., Dyachenko, V.P., etc. (2005), *Sovremennaya teoriya lentochnykh konveyerov gornykh predpriyatiy* [Modern theory of belt conveyers for mining enterprises], Iz-vo MGGU, Moscow, Russia.

2. Dyakov, V.F., Shakhmeyster, L.G., Dmitriev, V.G., etc. (1982), *Lentochnye konveyery v gornoy promyshlennosti* [Band conveyers in mining industry], in Spivakovskiy, A.O. (ed.), Nedra, Moscow, SU.

3. Shakhmeyster, L.G. and Solod, G.I. (1976), *Podzemnye konveyernye ustanovki* [Underground conveyer arrangement], in Spivakovskiy, A.O. (ed.), Nedra, Moscow, SU.

4. Perten, YU. A. (1977), *Krutonaklonnye konveyery* [Steeply inclined conveyors], Mashinostroenie (Leningr. otdelenie), Leningrad, SU.

5. Shakhmeyster, L.G. and Dmitriev, V.G. (1987), *Teoriya i raschet lentochnykh konveyerov* [Theory and calculation of belt conveyers], Mashinostroenie, Moscow, SU.

СПИСОК ЛИТЕРАТУРЫ

1. Современная теория ленточных конвейеров горных предприятий / В. И. Галкин, В. Г. Дмитриев, В. П. Дьяченко и др. М.: Из–во МГГУ, 2005. 543 с.

2. Ленточные конвейеры в горной промышленности / В. А. Дьяков, Л. Г. Шахмейстер, В. Г. Дмитриев и др. / Под ред. А. О. Спиваковского. М.: Недра, 1982. 349

3. Шахмейстер Л. Г., Солод Г. И. Подземные конвейерные установки / Под ред. А. О. Спиваковского. М.: Недра, 1976. 432 с.

4. Пертен Ю.А. Крутонаклонные конвейеры. Л.: Машиностроение (Ленингр. отделение), 1977. 216 с.

5. Шахмейстер Л. Г., Дмитриев В. Г. Теория и расчет ленточных конвейеров. М.: Машиностроение, 1987. 336 с.

About the authors

Kiriia Ruslan Visarionovych, Doctor of Technical Sciences (D. Sc.), Senior Researcher, Principal Researcher in Department of Geomechanics of Mineral Opencast Mining Technology, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM of NAS of Ukraine), Dnipro, Ukraine, kiriya.igtm@gmail.com

Monastyrskyi Vitalii Fedorovych, Doctor of Technical Sciences (D. Sc), Senior Researcher, Senior Researcher in Department of Geomechanics of Mineral Opencast Mining Technology, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM of NAS of Ukraine), Dnipro, Ukraine, vfmonas@gmail.com

Mishchenko Tamara Fedorivna, Master of Science, Senior Specialist in Department of Geomechanics of Mineral Opencast Mining Technology, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM of NAS of Ukraine), Dnipro, Ukraine, mishenkotamaraf@gmail.com

Mostovyi Borys Ivanovych, Master of Science, Principal Specialist in Department of Geomechanics of Mineral Opencast Mining Technology, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM of NAS of Ukraine), Dnipro, Ukraine, sly3@i.ua

Про авторів

Кірія Руслан Вісаріонович, доктор технічних наук, старший науковий співробітник, провідний науковий співробітник відділу геомеханічних основ технологій відкритої розробки родовищ, Інститут геотехнічної механіки ім. М. С. Полякова Національної академії наук України (ІГТМ НАН України), Дніпро, Україна, kiriya.igtm@gmail.com

Монастирський Віталій Федорович, доктор технічних наук, старший науковий співробітник, старший науковий співробітник відділу геомеханічних основ технологій відкритої розробки родовищ, Інститут геотехнічної механіки ім. М. С. Полякова Національної академії наук України (ІГТМ НАН України), Дніпро, Україна, vfmonas@gmail.com

Міщенко Тамара Федорівна, магістр, головний технолог відділу геомеханічних основ технологій відкритої розробки родовищ, Інститут геотехнічної механіки ім. М. С. Полякова Національної академії наук України (ІГТМ НАН України), Дніпро, Україна, mishenkotamaraf@gmail.com

Мостовий Борис Іванович, магістр, провідний інженер відділу геомеханічних основ технології відкритої розробки родовищ, Інститут геотехнічної механіки ім. М. С. Полякова Національної академії наук України (ІГТМ НАН України), Дніпро, Україна, sly3@i.ua

---

Анотація. Нині у зв'язку із заглибленням кар'єрів при видобутку корисних копалин набули широкого застосування крутопохилі конвеєри. Одним з поширених типів крутопохилих стрічкових конвеєрів є конвеєри з перегородками на стрічці. Цей тип конвеєрів застосовується в основному для дрібношматкових вантажів. Проте останнім часом їх почали використовувати для насипних вантажів, які включають окрім дрібношматкового вантажу ще й окремі шматки, максимальний розмір яких більше за 150 мм. Згідно з літературними джерелами граничний кут нахилу стрічкового конвеєра з перегородками знаходиться в межах від 35° до 60°. Проте до теперішнього часу не існує досліджень, що визначають залежність величин граничного кута нахилу стрічкового конвеєра з перегородками від параметрів конвеєра, розмірів перегородок і властивостей вантажу, що транспортується. В цій роботі на основі законів статики сипучого середовища визначено граничний кут нахилу стрічкового конвеєра з перегородками залежно від погонного навантаження насипного вантажу, що транспортується, висоти перегородок і відстані між ними, а також кута укосу насипного вантажу. В роботі розглянуто два випадки: випадок, коли сипучий вантаж між перегородками покриває всю стрічку конвеєра, і випадок, коли сипучий вантаж покриває частину стрічки конвеєра. В результаті встановлено, що в першому випадку тангенс граничного кута нахилу стрічкового конвеєра з перегородками із збільшенням погонного навантаження зменшується за лінійним законом, а в другому випадку, коли сипучий вантаж не повністю покриває стрічку конвеєра, тангенс граничного кута нахилу стрічкового конвеєра із збільшенням погонного навантаження зменшується за гіперболічним законом. При цьому зі збільшенням висоти перегородки граничний кут нахилу стрічкового конвеєра збільшується. Крім того, отримано залежність об'ємної продуктивності стрічкового конвеєра з перегородками від граничного кута нахилу конвеєра. При цьому зі збільшенням граничного кута нахилу стрічкового конвеєра продуктивність конвеєра зменшується, а зі збільшенням висоти перегородки – збільшується. Результати дослідження можуть бути використаними при проектуванні стрічкового конвеєра з перегородками на стрічці, що транспортує насипні вантажі.

Ключові слова: стрічкові конвеєри, насипний вантаж, перегородки на стрічці, граничний кут нахилу.

Аннотация. В настоящее время в связи с углублением карьеров при добыче полезных ископаемых получили широкое применение крутонаклонные конвейеры. Одним из распространенных типов крутонаклонных ленточных конвейеров являются конвейеры с перегородками на ленте. Этот тип конвейеров применяется в основном для мелкокусковых грузов. Однако в последнее время их стали использовать для насыпных грузов, включающих кроме мелкокускового груза еще и отдельные куски, максимальный размер которых более 150 мм. Согласно литературным источникам предельный угол наклона ленточного конвейера с перегородками находится в пределах от 35º до 60º. Однако до настоящего времени не существует исследований, определяющих зависимость величин предельного угла наклона ленточного конвейера с перегородками от параметров конвейера, размеров перегородок и свойств транспортируемого груза. В данной работе на основании законов статики сыпучей среды определен предельный угол наклона ленточного конвейера с перегородками в зависимости от погонной нагрузки транспортируемого насыпного груза, высоты перегородок и расстояния между ними, а также угла откоса насыпного груза. В работе были рассмотрены два случая: случай, когда сыпучий груз между перегородками покрывает всю ленту конвейера, и случай, когда сыпучий груз покрывает часть ленты конвейера. В результате установлено, что в первом случае тангенс предельного угла наклона ленточного конвейера с перегородками с увеличением погонной нагрузки уменьшается по линейному закону, а во втором случае, когда сыпучий груз не полностью покрывает ленту конвейера, тангенс предельного угла наклона ленточного конвейера с увеличением погонной нагрузки уменьшается по гиперболическому закону. При этом с увеличением высоты перегородки предельный угол наклона ленточного конвейера увеличивается. Кроме того, получены зависимости объемной производительности ленточного конвейера с перегородками от предельного угла наклона конвейера. При этом с увеличением предельного угла наклона ленточного конвейера производительность конвейера уменьшается, а с увеличением высоты перегородки – увеличивается. Результаты исследования могут быть использованы при проектировании ленточного конвейера с перегородками на ленте, транспортирующего насыпные грузы.

Ключевые слова: ленточные конвейеры, сыпучий груз, перегородки на ленте, предельный угол наклона.

The manuscript was submitted 27.05.2021