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Determination of the influence of a longitudinal cut on the tension state of a rubber strip tape

Powerful conveyors are equipped with rubber conveyor belts. They are used in various industries. Tapes are destroyed during operation. One of the forms of destruction is a longitudinal cut of the tape. The purpose of the article is to build an analytical algorithm for determining and studying the stress-strain state of a rubber cable belt with a longitudinal, limited-length cut, taking into account the construction of the belt, the mechanical properties of its components (cables and rubber layers), arbitrary longitudinal violation of its integrity and the arbitrary nature of the interaction of the belt with a drum The algorithm was developed on the basis of the formulation and solution of the model of the interaction of the tape cables. An arbitrarily located partial longitudinal section of any length is taken into account. The arbitrary nature of the interaction of the belt with the conveyor drum is taken into account. It was established that the cut of the tape affects its stress-strain state both in the area with damage and beyond, in particular, it reduces the localization zones of disturbances in the strips against the size of the disturbance zone in the tape. The disturbance zone decreases more in the strip with fewer cables. The total loads of the cables in the strips remain unchanged along their length. The practical significance of the developed algorithm lies in the fact that the use of the indicators of the stress-strain state of the belt with known damage determined with its help makes it possible to make reasonable technical decisions regarding the conditions of safe, temporary use of the conveyor, including the impulse loading of the material, which should be investigated in the future.

Keywords: *rubber conveyor belt; mechanical properties; longitudinal cut; stresses; deformations.*

Actuality of theme. Conveyor transport of considerable capacity is used in various technological processes. In particular, on blast furnaces with a volume of more than 2000 m^3, it is advisable to use conveyor-type elevators [1]. In Kryvyi Rih, the second largest metallurgical company in the world, operates a furnace of 5,000 m^3, in the Japanese city of Fukuyama, a furnace with a volume of 4,617 m^3 is operated. Conveyors on blast furnaces transport and form a multicomponent charge [2]. The dissertation [3] is devoted to the functioning of conveyor transport systems with a complex, branched structure in mining. The article [4] discusses the topic of creating systems for catching conveyor belts during their emergency failure. Attention was drawn to the need to detect accidental negative impacts on the conveyor belt. It is proposed to install the tape gust control system in the cross-section of the maximum forces acting on it.

Conveyor dosing and transportation systems include means of loading and overloading raw materials. Difficult operating conditions, significant volumes of transported material make it difficult to control the entry of foreign objects onto the conveyor. Such objects can get into the loading area of the conveyor where the belt load is minimal and no belt damage systems are installed. The latter can destroy the conveyor belt. The facts of longitudinal cutting of the tape by foreign objects are given in the dissertation [5]. Powerful conveyors are equipped with rubber conveyor belts. Significant speed of movement of the tape – up to 10 m/s, the construction of the rubber cable tape contributes to its destruction over considerable lengths. The cutting of the tape, the features of the conveyor design affect its stress-deformed state and the possibility of destruction. The known tension state of the belt allows you to make reasonable technical decisions regarding the conditions of safe temporary operation of the conveyor, for example, at the blast furnace, taking into account the technologically foreseen impulse supply of materials.

Analysis of the latest research and publications on which the author relies. The consequence of the longitudinal cut of a part of the tape is the formation of two stripes on the part of the tape. The load of these bands is different. The destruction of one belt can cause the destruction (rupture) of the second, respectively, the entire belt, the failure of the conveyor. The impact of gusts of the tape cables is analyzed in publications [6, 7]. Research [8] is aimed at improving methods of connecting conveyor belts. The effect of the number of cables [9], the step of their laying [10] on the properties of rubber conveyor belts and natural aging [11] on the strength indicators of their connections was studied. In [12], an analysis of methods for diagnosing the condition of rubber ropes was carried out. Works [13–14] dedicated to the study of the features of the tension state of ropes, tapes taking into account their interaction with machine elements, in particular, on the bobbin in [15], during the wear of elements of mine cableways in [16], in the presence of holes in the tape [17]. The influence of nonlinear changes in the shear modulus of the shell of a composite tensile element with a damaged structure on its stress state was studied in [18], and of a multi-layer rubber cable composite in [19]. The algorithm for calculating the stress-strain state of a rubber cable belt of unlimited length with longitudinal damage was developed in the article [20].

The purpose of the article is to establish the influence of the longitudinal, limited cutting length of the rubber conveyor belt on its stress-strain state.

Presentation of the main material. Consider a conveyor rubber cable belt of length L as a composite with hard (cables) and soft (rubber) layers. The number of cables will be equal to M. The tape is located along the x axis. The beginning of the axis coincides with the section of one end of the tape. Between the Nth and $N+1$ cables, it is cut at a length of δ. The beginning of the cut has the coordinate $x = l$ (Fig. 1).

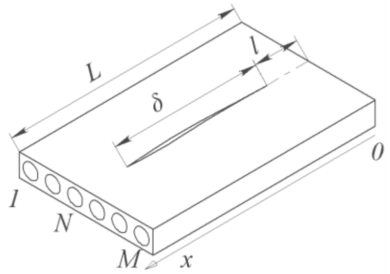

Fig. 1. Tape with a longitudinal cut

The cut of the tape divides it in a separate section into two parallel strips. They are attached to solid parts. Let's assume that the cut of the tape is located symmetrically to its ends. The conditions for attaching the tape to the structural elements of the conveyor also have a symmetrical character. Consider the symmetrical part of the tape. The internal load forces and deformation of the ropes of the part of the belt without damage, in the section $0 \leq x \leq l$, have the form [20].

$$p_i = E \cdot F,$$

$$p_i = E \cdot F \sum_{m=1}^{M-1} \left(A_m e^{\beta_m x} - B_m e^{-\beta_m x}\right) \beta_m c(\mu_m, i) + \frac{P_0}{N}, \quad (1)$$

$$u_i = \sum_{m=1}^{M-1} \left(A_m e^{\beta_m x} - B_m e^{-\beta_m x}\right) c(\mu_m, i) + \frac{P_0 x}{N \cdot E \cdot F} + u_0, \quad (2)$$

where A_m, B_m are unknown constants;

i – cable number ($i = 1, 2, \dots M$);

E, F – composite tensile modulus and cross-sectional area of the cable;

$\beta_m = \sqrt{2 \frac{x}{EF} (1 - \cos\mu_m)}$;

$\mu_m = \pi \frac{m}{N}$;

χ – stiffness of the layers of the rubber shell of the tape against shear;

$c(\mu_m, i) = \cos\left(\mu_m (i - 0{,}5)\right)$;

u_0. – displacement of the tape as a rigid body;

P_0 – tape load force.

Expressions (1) and (2) have independent components and components (in the form of sums) dependent on the numbers of cables. The first reproduce the patterns of load and deformation of the tape as a single system of parallel cables under the influence of external longitudinal load. The second is only the redistribution of forces between the ropes in the tape and the deformation of its section, therefore

$$\sum_{i=1}^{M} \sum_{m=1}^{M-1} \left(A_m e^{\beta_m x} - B_m e^{-\beta_m x}\right) \beta_m c(\mu_m, i) = 0, \quad (3)$$

$$\sum_{i=1}^{M} \sum_{m=1}^{M-1} \left(A_m e^{\beta_m x} - B_m e^{-\beta_m x}\right) c(\mu_m, i) = 0. \quad (4)$$

During operation, deviations in the relative position of the drum and the conveyor belt are possible. In order to solve the problem in a general form, we will assume that the belt in the section $x = 0$ is connected to the conveyor in such a way that the ratio of the coefficients in the expressions (1) and (2) takes place.

$$A_m = a_m - b_m B_m, \quad (5)$$

where a_m, b_m – are the coefficients characterizing the nature of joining the tape to the conveyor drum.

Longitudinal cutting of the tape leads to the creation of two strips on its part. In general, the mechanism of interaction of the cables in the created strips does not change. The cables closest to the cut stop interacting with each other. They become extreme in streaks. In the continuous tape, these cables have the numbers N and $N+1$. They are the first in the stripes. The stress-strain state of the strips can be determined by dependencies (1) and (2) provided that the number of cables in each strip, the load and displacement of the strips as rigid bodies are taken into account.

For convenience, the strips are identified by the numbers I and II with the number of cables, N and M-N, respectively. The numbers of the bands will be added to the superscripts of the values relating to specific bands. The displacement and internal load forces of the ropes of the strips, according to (1) and (2), will take the following forms.

$$u_i^I = \sum_{n=1}^{N-1}\left(A_n^I e^{\beta_n^I x} + B_n^I e^{-\beta_n^I x}\right)c(\mu_n^I, i) + \frac{P^I(x-l)}{N\cdot E\cdot F} + u_0^I,$$
$$p_i^I = E\cdot F\sum_{n=1}^{N-1}\left(A_n^I e^{\beta_n^I x} - B_n^I e^{-\beta_n^I x}\right)\beta_n^I c(\mu_n^I, i) + \frac{P^I}{N}, \qquad (6)$$

$(1 \leq i \leq N)$

$$u_i^{II} = \sum_{n=1}^{M-N-1}\left(A_n^{II} e^{\beta_n^{II} x} + B_n^{II} e^{-\beta_n^{II} x}\right)c(\mu_n^{II}, i) + \frac{P^{II}(x-l)}{(M-N)\cdot E\cdot F} + u_0^{II}\ ,$$
$$p_i^{II} = E\cdot F\sum_{n=1}^{N-1}\left(A_n^{II} e^{\beta_n^{II} x} - B_n^{II} e^{-\beta_n^{II} x}\right)\beta_n^{II} c(\mu_n^{II}, i) + \frac{P^{II}}{(M-N)}, \qquad (7)$$

$(N < i \leq M)$

where $A_n^I, B_n^I, A_n^{II}, B_n^{II}$ – unknown constants;

P^I, P^{II} – loads acting on the strips;

$\mu_n^I = \frac{\pi n}{N}$;

$\mu_n^I = \frac{\pi n}{M-N}$;

$\beta_n^I = \sqrt{2\frac{x}{EF}(1-\cos\mu_n^I)}$;

$\beta_n^{II} = \sqrt{2\frac{x}{EF}(1-\cos\mu_n^{II})}$;

u_0^I, u_0^{II} – are the displacements of the tape strips as rigid bodies.

In the expressions of movements and loads of cables (1), (2), (6), (7), the vectors of the characteristic indicators β_m, $\beta^I{}_n$, $\beta^{II}{}_n$ are distinct. They, as one of the coefficients of the arguments of the exponents, are part of the expressions of the indicators of the stress-strain state of the tape. As the number of cables in the strip decreases, the value of the component vectors of the characteristic indicators increases. Their decrease, with an unchanged coefficient - the x coordinates, reduces the value of the exponents. Accordingly, it reduces the zone of localization of disturbances in the strips against the zones of disturbances in the tape and reduces more in the strip with fewer cables. The total loads of the cables in the strips remain unchanged along their length. They are determined by the values of P^I, P^{II}.

Stripes are parts of a ribbon. In the cross-section of the beginning of its cut (x = l), the conditions of compatibility of deformation of the parts of the tape must be met.

$$u_i^I = u_i \wedge p_i^I = p_i \qquad (1 \leq i \leq N), \qquad (8)$$

$$u_i^{II} = u_{I,i} \wedge p_i^{II} = p_{I,i} \qquad (\mathrm{N}+1 \leq i \leq M). \qquad (9)$$

To fulfill the first parts of conditions (8) and (9), the movement of the ropes of the strips in the section x = l is given by Fourier series on the discrete axes of the numbers of the ropes at limited intervals: $1 \leq I \leq N$ and $N < i \leq M$. As the coefficients of the series, we will take the components of the sums of the movements of the cables of the first part of the tape in the section $x = l$.

$$u_i^I = \frac{2}{N}\sum_{j=1}^{N}\sum_{n=1}^{N-1}\sum_{m=1}^{M-1}\left(a_m e^{\beta_m l} + B_m\left(e^{-\beta_m l} - b_m e^{\beta_m l}\right)c(\mu_m, j)c(\mu_n^I, j)c(\mu_n^I, i),\right. \qquad (10)$$

$(1 \leq i \leq N \wedge x =$

$$u_i^I = \frac{2}{M-N}\sum_{j=N+1}^{M}\sum_{n=1}^{M-N-1}\sum_{m=1}^{M-1}\left(a_m e^{\beta_m l} + B_m\left(e^{-\beta_m l} - \right.\right.$$
$$\left.\left. - b_m e^{\beta_m l}\right)\right)c(\mu_m, j)c(\mu_n^{II}, j)c(\mu_n^{II}, i), \qquad (11)$$

$(\mathrm{N} < i \leq M \wedge x =$

From the accepted condition of symmetry of the cut conveyor belt, the following ratios of coefficients in expressions (6) and (7) hold.

$$A_i^I = -B_i^I e^{-\beta_n^I L};\quad A_i^{II} = -B_i^{II} e^{-\beta_n^{II} L}.$$

Let's take into account the obtained ratios. Expressions of values of movements and loads of cables (6) and (7) will take the following forms:

For: $(1 \leq i \leq N)$

$$u_i^I = \sum_{n=1}^{N-1} B_i^I\left(e^{-\beta_n^I x} - e^{-\beta_n^I (x-L)}\right)c(\mu_n^I, i) + \frac{P^I(x-l)}{NEF} + u_0^I, \qquad (12)$$

$$p_i^I = -EF\sum_{n=1}^{N-1} B_i^I\left(e^{-\beta_n^I x} + e^{-\beta_n^I (x-L)}\right)\beta_n^I c(\mu_n^I, i) + \frac{P^I}{N}. \qquad (13)$$

For: $(N < i \leq M)$

$$u_i^{II} = \sum_{n=1}^{M-N-1} B_i^{II}\left(e^{-\beta_n^{II} x} - e^{-\beta_n^{II}(x-L)}\right)c(\mu_n^{II}, i) + \frac{(P_0-P^I)(x-l)}{(M-N)EF} + u_0^{II}, \qquad (14)$$

$$p_i^{II} = -EF\sum_{n=1}^{M-N-1} B_i^{II}(e^{-\beta_n^{II}x} + e^{-\beta_n^{II}(x-L)})\beta_n^{II} c(\mu_n^{II}, i) + \frac{(P_0 - P^I)}{M-N}. \quad (15)$$

Let's note. Expressions (14) and (15) take into account the equilibrium condition:

$$P^{II} = P_0 - P^I.$$

We equate dependencies (10) and (11), respectively, to expressions (12) and (14) in the section x = l. We will get

$$\sum_{n=1}^{N-1} B_i^I(e^{-\beta_n^I l} - e^{-\beta_n^I(l-L)})c(\mu_n^I, i) + u_0^I = \quad (16)$$

$$= \frac{2}{N}\sum_{j=1}^{N}\sum_{n=1}^{N-1}\sum_{m=1}^{M-1}(a_m e^{\beta_m l} + B_m(e^{-\beta_m l} - b_m e^{\beta_m l}))(1 + \frac{1}{N})c(\mu_m, j)c(\mu_n^I, j)c(\mu_n^I, i) + u_0,$$

$(1 \le i \le N)$

$$\sum_{n=1}^{M-N-1} B_i^{II}(e^{-\beta_n^{II}x} - e^{-\beta_n^{II}(x-L)})c(\mu_n^{II}, i) + u_0^{II} =$$

$$= \frac{2}{M-N}\sum_{j=N+1}^{M}\sum_{n=1}^{M-N-1}\sum_{m=1}^{M-1}(a_m e^{\beta_m l} + B_m(e^{-\beta_m l} - b_m e^{\beta_m l}))\left(1 + \frac{1}{M-N}\right)c(\mu_m, j)c(\mu_n^{II}, j) \times \quad (17)$$

$$\times c(\mu_n^{II}, i) + u_0$$

$(N < i \le M)$.

Expressions (16) and (17) take into account the fact that the movement of the strips as solid bodies is equal to the average movement of the cables of the undamaged section of the strip at the border of the parts of the strip with damage and without damage, namely.

$$u_0^I = \sum_{j=1}^{N}\sum_{m=1}^{M-1}(A_{1.m}e^{\beta_m l} + B_{1.m}e^{-\beta_m l})\frac{c(\mu_m, j)}{N} + u_0,$$

$$u_0^{II} = \sum_{j=N+1}^{M}\sum_{m=1}^{M-1}(A_{1.m}e^{\beta_m l} + B_{1.m}e^{-\beta_m l})\frac{c(\mu_m, j)}{M-N} + u_0.$$

From (16) and (17) we have the values of the coefficients of the unknown expressions of movements and the distribution of load forces of the ropes of the strips.

$$B_i^I = \frac{2\sum_{j=1}^{N}\sum_{m=1}^{M-1}(a_m e^{\beta_m l} + B_m(e^{-\beta_m l} - b_m e^{\beta_m l}))c(\mu_m, j)c(\mu_n^I, j)}{N(e^{-\beta_n^I l} - e^{-\beta_n^I(l-L)})}, \quad (18)$$

$$B_i^{II} = \frac{2\sum_{j=N+1}^{M}\sum_{m=1}^{M-1}(a_m e^{\beta_m l} + B_m(e^{-\beta_m l} - b_m e^{\beta_m l}))c(\mu_m, j)c(\mu_n^{II}, j)}{(M-N)(e^{-\beta_n^{II} l} - e^{-\beta_n^{II}(l-L)})}. \quad (19)$$

Note that under the conditions of uniform load of the cables or equal movement of them in the cross-section of the connection of the belt to the conveyor, the nature of the movements of the cables and their loads does not depend on the cut of the belt - it corresponds to the uniform deformation of the belt. The redistribution of forces and movements of the cables will take place in case of violation of the uniform distribution of loads or deformations of the tape in any of its sections. Let's take the following values of the coefficients in expression (5).

$$a_m = \frac{2}{M}U_0 c(\mu_m, j), b_m = 1, \quad (20)$$

where U_0 – some, unknown movement of the end of the J-thcable in the section x = 0 is associated with a defect in the interaction of the conveyor drum and the belt.

Distribution of forces between cables from (1) taking into account (20)

$$p_i = EF\sum_{m=1}^{M-1}(\frac{2}{M}U_0 c(\mu_m, j)e^{\beta_m x} - B_m(e^{-\beta_m x} + e^{\beta_m x})\beta_m c(\mu_m, i) + \frac{P_0}{M}.$$

Under the accepted values, all the ropes of the tape are fixedly connected, except for the rope numbered J. We will assume that the movement corresponds to the break of the J-thrope. Under such conditions, its load is zero. Accordingly, the displacement of the end of the J-th cable in the section x = 0 is unknown x = 0.

$$U_0 = -\frac{M\sum_{m=1}^{M-1} B_m\beta_m c(\mu_m, j) + \frac{P_0}{EF}}{\sum_{m=1}^{M-1} c(\mu_m, j)^2\beta_m}.$$

The average movement of all M cables of the entire belt section.

$$u_0 = \frac{U_0}{M}.$$

$$p_i = EF\sum_{m=1}^{M-1}\left[-2\frac{\sum_{m=1}^{M-1} B_m\beta_m c(\mu_m, j) + \frac{P_0}{MEF}}{\sum_{m=1}^{M-1} c(\mu_m, j)^2\beta_m}c(\mu_m, j)e^{\beta_m x} - B_m(e^{-\beta_m x} + \right.$$

$$\left. + e^{\beta_m x}\right]\beta_m c(\mu_m, i) + \frac{P_0}{M}, \quad (21)$$

$$u_i = \sum_{m=1}^{M-1}\left[-2\frac{\sum_{m=1}^{M-1} B_m\beta_m c(\mu_m, j) + \frac{P_0}{MEF}}{\sum_{m=1}^{M-1} c(\mu_m, j)^2\beta_m}c(\mu_m, j)e^{\beta_m x} + \right.$$

$$\left. + B_m(e^{-\beta_m x} + e^{\beta_m x}\right]c(\mu_m, i) + \frac{P_0 x}{MEF} + \frac{1}{M}U_0. \quad (22)$$

The formulated expressions for the loads of the ropes of the tape (21) of its part without a longitudinal cut, the second parts of the conditions (8) and (9), the expressions of the loads of the ropes of the strips formed by cutting (13), (15), the values of the coefficients (18), (19) allow to make *M*-1 equations of force equality for *M*-1 rope. The condition of equality of the loading forces of the first *N* cables (21) of the part of the tape without a longitudinal cut of the force *PI* will complement the above equations to the system of equations of order *M*. The solution of the system will allow to determine all (*M*-1) values of the vector of coefficients *Bm* and the unknown force *PI*. The known movements of the cables make it possible to determine the tangential stresses in the elastic layers of the tape according to Hooke's law. Together, the above is an algorithm for determining the stress-strain state of the tape caused by the cut of the tape, taking into account the conditions of interaction of the tape with the conveyor drums.

Conclusions. Powerful conveyors are used in various technological processes. As a rule, they are equipped with rubber bands. The method of determining the effect of a local (limited in length) cut of the tape on its stress-strain state has not been developed. For the rubber rope tape, as a composite with hard and soft layers, with the arbitrary nature of joining to the drums, the symmetrical arrangement of the longitudinal cut of the tape relative to them, an algorithm for determining its stress-strain state was formed. At the same time, it is taken into account that the longitudinal cut of the tape changes (eliminates) the mechanism of interaction of the cables closest to it. Violation of the interaction of two cables adjacent to the damage affects the stress-strain state of the tape both in the area with the damage and beyond, in particular, it reduces the localization zones of disturbances in the strips against the size of the disturbance zone in the tape. With a smaller number of cables in the strip, the disturbance zone is smaller. The total loads of the cables in the strips remain unchanged along their length. The developed algorithm makes it possible to determine the stress-strain state of a tape with a local cut. The known values of the latter make it possible to make informed technical decisions regarding the conditions of safe, temporary use of the conveyor, including the impulse loading of material onto the conveyor in the same way as the charge supplied to the blast furnace is loaded. The use of cyclic feeding of materials with partial destruction of the tape will be further studied in the following studies.

References:

1. *Селегей А.М.* Розвиток наукових основ управління завантаженням доменної печі шихтовими матеріалами з урахуванням їх дисперсності : дис. … д.т.н. : 05.16.02 / *А.М. Селегей*. – Дніпро : Національна металургійна академія України, 2021. – 368 с.
2. Модель управління формуванням багатокомпонентних порцій шихти на доменному конвеєрі / *М.О. Рибальченко, А.М. Селегей, В.І. Головко та ін.* // Наука та інновації. – 2020. – Т. 16 (6). – С. 36–45.
3. *Кірія Р.В.* Моделювання процесів функціонування систем конвеєрного транспорту зі складною структурою і методи підвищення їх ефективності : дис. … д.т.н. : 01.05.02 / *Р.В. Кірія*. – Дніпро : Інститут геотехнічної механіки ім. М.С. Полякова, 2018. – 386 с.
4. *Драбчук А.М.* Потенціал залучення інформаційних технологій для підвищення надійності роботи конвеєрних систем / *А.М. Драбчук, Ю.П. Калініченко* // Гірничий вісник. – 2015. – Вип. 99. – С. 124–128.
5. *Гринько П.А.* Обґрунтування конструктивних параметрів барабанів стрічкових конвеєрів що забезпечують збільшення довговічності стрічок : дис. ... к.т.н. : 05.05.05 / *П.А. Гринько*. – Одеса : Одеський національний політехнічний університет, 2015. – 157 с.
6. Examination of the process of damaging the top covering layer of a conveyor belt applying the FEM / *D.Marasová, Ľ.Ambriško, M.Andrejiová, A.Grinčová* // Journal of the International Measurement Confederation. – 2017. – Vol. 112. – P. 47–52.
7. Analysis of core failure distribution in steel cord belts on the cross-section / *R.Blazej, L.Jurdziak, R.Burduk and other* // International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 29 June – 5 July. – Albena, Bulgaria, 2017. – Vol. 17. – P. 987–994.
8. *Чуб В.О.* Удосконалення способів ремонту та з'єднання гумовотканинних конвеєрних стрічок / *В.О. Чуб, П.А. Дьячков* // Молодь: наука та інновації: зб. матеріалів доп. учасн. X Міжнародної науково-технічної конференції студентів, аспірантів та молодих вчених. – Дніпро : Дніпровська політехніка, 2022. – С. 138 –139.
9. *Long X.* Analysis of influence of multiple steel cords on splice strength / *X.Long, X.Li, H.Long* // Journal of Adhesion Science and Technology. – 2018. – Vol. 32, № 24. – P. 2753–2763.
10. Influence of different cord pitch on the pullout force of steel cord conveyor belt splice / *X.Li, X.Long, H.Jiang, H.Long* // Journal of Adhesion Science and Technology. – 2018. – Vol. 32, № 20. – P. 2268–2281.
11. *Bajda M.* The influence of natural ageing processes on the strength parameters of steel cord conveyor belts / *M.Bajda, M.Hardygóra* // International Journal of Mining, Reclamation and Environment. – 2018. – Vol. 32, № 6. – P. 430–439.
12. *Швачка А.В.* Аналіз існуючих засобів діагностики для каната зі змінним перетином: огляд / *А.В. Швачка* // Молодий вчений. – 2021. – № 1 (89). – С. 17–19. DOI: 10.32839/2304-5809/2021-1-89-4.
13. Assessment of Padding Elements Wear of Belt ConveyorsWorking in Combination of Rubber-Quartz-Metal Condition / *D.Romek, D.Ulbrich, J.Selech and other* // Materials (Basel). – 2021. – Vol. 14 (15). – P. 4323. DOI: 10.3390/ma14154323.
14. *Yao Y.* Influence of the elastic modulus of a conveyor belt on the power allocation of multi-drive conveyors / *Y.Yao, B.Zhang* // PLOS One. – 2020. – Vol. 15 (7). DOI: 10.1371/journal.pone.0235768.

15. Influence of parameters of a rubber-rope cable on the torsional stiffness of the body of the winding / *K.S. Zabolotnyi, O.V. Panchenko, O.L. Zhupiiev, M.V. Polushyna* // Scientific Bulletin of National Mining University. – 2018. – Issue 5. – P. 54–63.
16. Reducing Wear of the Mine Ropeways Components Basing Upon the Studies of Their Contact Interaction / *J.S. Haddad, O.Denyshchenko, D.Kolosov and other* // Archives of Mining Sciences. – 2021. – № 66 (4). – P. 579 –594. DOI: 10.24425/ams.2021.139598.
17. Алгоритм розрахунку на міцність конвеєрної стрічки з отворами : збірник наукових праць Дніпровського державного технічного університету (технічні науки) / *І.В. Бельмас, Д.Л. Колосов, О.І. Білоус та ін.* – Каменське : ДДТУ, 2020. – Тематичний вип.: Теорія, технологія та машини обробки металів. – С. 86–95.
18. Influence of Nonlinear Shear Modulus Change of Elastomeric Shell of a Composite Tractive Element with a Damaged Structure on its Stress State. Inżynieria Mineralna / *I.Belmas, D.Kolosov, S.Onyshchenko and other* // Journal of the Polish Mineral Engineering Society. – 2023. – № 1 (51). – P. 155–162. DOI: 10.29227/IM-2023-01-18.
19. *Бельмас І.В.* Визначення напружено-деформованого стану багатошарового композиту / *І.В. Бельмас, О.І. Білоус, Г.І. Танцура* // Опір матеріалів та теорія споруд. – Київ : Київський національний університет будівництва і архітектури, 2022. – № 109. – С. 426–440.
20. Algorithm for calculating the stress condition of the conveyor tape with its longitudinal damage / *I.Belmas, O.Bilous, H.Tantsura and other* // Математичне моделювання. – 2023. – № 1 (48). – С. 97–106.

References:

1. Selehei, A.M. (2021), «Rozvytok naukovykh osnov upravlinnia zavantazhenniam domennoi pechi shykhtovymy materialamy z urakhuvanniam yikh dyspersnosti», D.Sc. Thesis of dissertation, 05.16.02, Natsionalna metalurhiina akademiia Ukrainy, Dnipro, 368 p.
2. Rybalchenko, M.O., Selehei, A.M., Holovko, O.S. et al. (2020), «Model upravlinnia formuvanniam bahatokomponentnykh portsii shykhty na domennomu konveieri», *Nauka ta innovatsii*, Vol. 16 (6), pp. 36–45.
3. Kiriia, R.V. (2018), «Modeliuvannia protsesiv funktsionuvannia system konveiernoho transportu zi skladnoiu strukturoiu i metody pidvyshchennia yikh efektyvnosti», D.Sc. Thesis of dissertation, 01.05.02, Instytut heotekhnichnoi mekhaniky im. M.S. Poliakova, Dnipro, 386 p.
4. Drabchuk, A.M. and Kalinichenko, Yu.P. (2015), «Potentsial zaluchennia informatsiinykh tekhnolohii dlia pidvyshchennia nadiinosti roboty konveiernykh system», *Hirnychyi visnyk*, Issue 99, pp. 124–128.
5. Hrynko, P.A. (2015), «Obgruntuvannia konstruktyvnykh parametriv barabaniv strichkovykh konveieriv shcho zabezpechuiut zbilshennia dovhovichnosti strichok», Ph.D. Thesis of dissertation, 05.05.05, Odeskyi natsionalnyi politekhnichnyi universytet, Odesa, 157 p.
6. Marasová, D., Ambriško, Ľ., Andrejiová, M. and Grinčová, A. (2017), «Examination of the process of damaging the top covering layer of a conveyor belt applying the FEM», *Journal of the International Measurement Confederation*, Vol. 112, pp. 47–52.
7. Blazej, R., Jurdziak, L., Burduk, R. et al. (2017), «Analysis of core failure distribution in steel cord belts on the cross-section», *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM*, Albena, Bulgaria, 29 June–5 July, Vol. 17, pp. 987–994.
8. Chub, V.O. and Diachkov, P.A. (2022), «Udoskonalennia sposobiv remontu ta ziednannia humovotkanynnykh konveiernykh strichok», *Molod: nauka ta innovatsii*, zb. mat. dop. uchasn. X Mizhnarodnoi naukovo-tekhnichnoi konferentsii studentiv, aspirantiv ta molodykh vchenykhiu, Dniprovska politekhnika, Dnipro, pp. 138–139.
9. Long, X., Li, X. and Long, H. (2018), «Analysis of influence of multiple steel cords on splice strength», *Journal of Adhesion Science and Technology*, Vol. 32, No. 24, pp. 2753–2763.
10. Li, X., Long, X., Jiang, H. and Long, H. (2018), «Influence of different cord pitch on the pullout force of steel cord conveyor belt splice», *Journal of Adhesion Science and Technology*, Vol. 32, No. 20, pp. 2268–2281.
11. Bajda, M. and Hardygóra, M. (2018), «The influence of natural ageing processes on the strength parameters of steel cord conveyor belts», *International Journal of Mining, Reclamation and Environment*, Vol. 32, No. 6, pp. 430–439.
12. Shvachka, A.V. (2021), «Analiz isnuiuchykh zasobiv diahnostyky dlia kanata zi zminnym peretynom: ohliad», *Young Scientist*, No. 1 (89), pp. 17–19, doi: 10.32839/2304-5809/2021-1-89-4.
13. Romek, D., Ulbrich, D., Selech, J. et al. (2021), «Assessment of Padding Elements Wear of Belt ConveyorsWorking in Combination of Rubber-Quartz-Metal Condition», *Materials (Basel)*, Vol. 14 (15), pp. 4323, doi: 10.3390/ma14154323.
14. Yao, Y. and Zhang, B. (2020), «Influence of the elastic modulus of a conveyor belt on the power allocation of multi-drive conveyors», *PLOS One*, Vol. 15 (7), doi: 10.1371/journal.pone.0235768.
15. Zabolotnyi, K.S., Panchenko, O.V., Zhupiiev, O.L. and Polushyna, M.V. (2018), «Influence of parameters of a rubber-rope cable on the torsional stiffness of the body of the winding», *Scientific Bulletin of National Mining University*, Issue 5, pp. 54–63.
16. Haddad, J.S., Denyshchenko, O., Kolosov, D. et al. (2021), «Reducing Wear of the Mine Ropeways Components Basing Upon the Studies of Their Contact Interaction», *Archives of Mining Sciences*, No. 66 (4), pp. 579–594, doi: 10.24425/ams.2021.139598.
17. Belmas, I.V., Kolosov, D.L., Bilous, O.I. et al. (2020), *Alhorytm rozrakhunku na mitsnist konveiernoi strichky z otvoramy*, Zbirnyk naukovykh prats Dniprovskoho derzhavnoho tekhnichnoho universytetu (tekhnichni nauky), DDTU, Tematychnyi vypusk *Teoriia, tekhnolohiia ta mashyny obrobky metaliv*, Kamenske, pp. 86–95.
18. Belmas, I., Kolosov, D., Onyshchenko, S. et al. (2023), «Influence of Nonlinear Shear Modulus Change of Elastomeric Shell of a Composite Tractive Element with a Damaged Structure on its Stress State. Inżynieria Mineralna», *Journal of the Polish Mineral Engineering Society*, No. 1 (51), pp. 155–162, doi: 10.29227/IM-2023-01-18.

19. Belmas, I.V., Bilous, O.I. and Tantsura, H.I. (2022), «Vyznachennia napruzheno-deformovanoho stanu bahatosharovoho kompozytu», *Opir materialiv ta teoriia sporud*, Kyivskyi natsionalnyi universytet budivnytstva i arkhitektury, No. 109, pp. 426–440.
20. Belmas, I., Bilous, O., Tantsura, H. et al. (2023), «Algorithm for calculating the stress condition of the conveyor tape with its longitudinal damage», *Matematychne modeliuvannia*, No. 1 (48), pp. 97–106.

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Визначення впливу поздовжнього порізу на напружений стан гумотросової стрічки

Потужні конвеєри обладнані гумотросовими стрічками. Вони використовуються в різних виробництвах. Стрічки в процесі експлуатації руйнуються. Однією з форм руйнування є поздовжній поріз стрічки. Мета статті полягає в побудові аналітичного алгоритму визначення та дослідження напружено-деформованого стану гумотросової стрічки з поздовжнім, обмеженої довжини порізом, з комплексним урахуванням конструкції стрічки, механічних властивостей її складових (тросів та гумових прошарків), довільного поздовжнього порушення її цілісності та довільного характеру взаємодії стрічки з барабаном. Алгоритм складено на основі формулювання та розв'язання моделі взаємодії тросів стрічки. Враховано довільним чином розташоване, довільної довжини часткове її поздовжнє розрізання. Враховано довільний характер взаємодії стрічки з барабаном конвеєра. Встановлено що поріз стрічки впливає на її напружено-деформований стан і на ділянці з ушкодженням і за її межами, зокрема, він зменшує зони локалізації збурень в смугах проти розміру зони збурення в стрічці. Більше зменшується зона збурення в смузі з меншою кількістю тросів. Сумарні навантаження тросів в смугах залишаються незмінними по їх довжині. Практична значущість розробленого алгоритму полягає в тому що використання визначених за його допомогою показників напружено-деформованого стану стрічки з відомим пошкодженням дозволяє приймати обґрунтовані технічні рішення стосовно умов безпечного, тимчасового використання конвеєра, включно з імпульсним завантаженням матеріалу, яке в подальшому доцільно дослідити.

Ключові слова: гумотросова конвеєрна стрічка; механічні властивості; поздовжній поріз; напруження; деформації.

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