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Improving Transportation Efficiency Belt Conveyor with Intermediate Drive

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Modern industry in the XXI century requires high-performance and fully automated technology. The best way to meet these requirements is the introduction of new progressive technologies in the process of transportation.

One of the possible ways to increase productivity, as well as automate the process of transportation, is the transition from cyclic machines to continuous transport, namely to belt conveyors. However, with the increase in the length of the conveyor there is a need for stronger belts. This can be avoided by using intermediate drives of various designs.

The article describes the principle of operation of the intermediate linear drive with transverse partitions, provides formulas for calculating the values of the tractive effort, gives comparative graphs showing the effectiveness of the use of an intermediate drive in various conditions. The possibilities of increasing the capacity of an intermediate linear drive are described.

Key words**:** bet conveyor; linear actuator; intermediate drive; partitions; tension

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Introduction. The current trend in the design of belt conveyors is an increase in the length of conveyor lines, which entails an increase in the length of the conveyor in one stage, and this in turn makes it possible to increase the reliability of the entire conveyor line and reduce costs [7, 18].

Currently, a significant number of design solutions and innovative technologies have been proposed, allows to solve the issues of the full automation of the process of transporting and introducing high-speed technologies [8, 14]

Using longer conveyors requires solving the problem of conveyor drives.

It is known that the traction force is transferred to the belt by friction, which cannot exceed a strictly defined value, which is described by the Euler – Zhukovsky formula:

$$F_{\max} = S_{\text{ro}}(e^{\mu\alpha} - 1),$$

где $F_{\max}$ – maximum traction force, N; S_{ro} – belt tension at the running-off point from the drive drum, N; $e^{\mu\alpha}$ – traction factor; α – belt wrap angle of drive drums; μ – friction coefficient.

Only two parameters influence the maximum possible traction force: belt tension and the number of driving drums, which inevitably affects the necessary strength of conveyor belts [6, 10].

Formulation of the problem. In recent years, requirements for mineral transportation systems have increased due to increased productivity and increased length of conveyor systems. This is especially applicable to development systems with long pillars. The requirements associated with these improvements were identified, and, since the development of the technology allowed producing more durable conveyor belts, the necessary equipment for belt conveyors was developed that meets these requirements [5, 7].

With an increase in the length of the panel manifest problems with transportation. The drive power and the strength of the belts required for a conveyor length of 4-5 km reach values that are much larger than those used in the underground mining of mineral deposits. The problems also include the large size of high-power drive stations, which does not allow them to be used and moved in conditions of limited underground workings. And, although manufacturers of conveyor belts can create a belt of greater strength capable of withstanding considerable loads, this leads to the need to reinforce the ribbon frame with steel cables, which makes the belt heavier and, more important, requires vulcanized butt joints [4, 13].

Since the face-bottom conveyor belts are constantly moving and retreating (becoming longer or shorter), miners are constantly forced to add or remove rolls of conveyor belt from the system. Moreover, since the creation of a vulcanized butt joint takes several times longer, the lost production time due to the displacement of the tape along the panel during development and production will be extreme [17].

One of the possible ways to solve such problems is the introduction of intermediate drives for belt conveyors.

Intermediate linear drive is a closed loop, which is located inside the contour of the main conveyor. The load-carrying branch of the main conveyor belt and the upper branch of the intermediate linear-drive belt interact with each other through friction forces. Installation of several intermediate linear drives is possible. In this case, each intermediate drive overcomes the resistance only of its part of the conveyor and provides maximum traction ability at a constant level. The scope of application of multi-drive belt conveyors is expanding, while technical and economic indicators are significantly improved as a result of the fact that the inclination angle of the conveyor does not affect the efficiency of using intermediate drives of this design, and the length of the intermediate drive is thus reduced [3].

The traction occurs on the surfaces of the frictional contact of the tape with the drive drum or with the tape of the linear drive. The transmitted traction force should not cause slipping on the drive drum, but at the same time provide for overcoming the forces of resistance.

Compared to the conventional method of transferring the traction force to a conveyor belt by wrapping a belt around one or more driving drums, the intermediate drive transmits the pulling force linearly through frictional contact with the main belt. The traction element is an endless closed belt of the intermediate drive, which is in contact with the underside of the load-carrying branch of the main conveyor and lies on the roller supports of the main load-carrying tape [12].

The pressure for transmitting force is the result of a combination of the weight of the belt and the material being transported. Although the specific pressure is much less than is achieved in the usual way, the increased hooking length between the belts provides the required thrust force.

A mathematical model of an intermediate linear drive with pinch rollers and the effectiveness of a linear drive for a conveyor line were considered in articles [2, 14, 15]. Another type of intermediate drive was patented at the St. Petersburg Mining Institute [1].

Methodology. The technical result of the invention is achieved due to the fact that at a distance equal to the position of the roller supports of the load-carrying branch of the main conveyor, transverse partitions are placed, which are rigidly fixed on the outer surface of the belt of the intermediate drive of the belt conveyor. The cross-sectional shape of the partitions can be curvilinear or rectangular with rounded upper edges. Partitions can be made of elastic or rigid material.

The intermediate drive is located inside the closed loop of the main conveyor so that its lower branch is supported by partitions on the idle branch of the main conveyor belt. In order to be able to provide transverse bending of the belt when it is supported on the roller carriages of a grooved form, the transverse partitions are formed from three parts located at a short distance from each other.

The operation of the intermediate linear drive is described as follows: the traction force from the drive belt is transferred to the load-carrying branch of the conveyor belt when the drive drum rotates both by the friction force caused by the weight of the load-carrying branch of the tape with the load placed on it and the load-carrying tape a branch of the conveyor due to the deflection between partitions caused by the action of its own weight and the weight of the load placed on the belt. The friction force between the belt and the partitions on the intermediate drive belt increases significantly, which leads to an increase in traction effort, which is realized by an intermediate linear drive and further increases due to the stop of the transverse partitions in the idle branch of the conveyor belt. The physicomechanical properties of the transported load influence the choice of material and the cross-sectional shape of the partitions.

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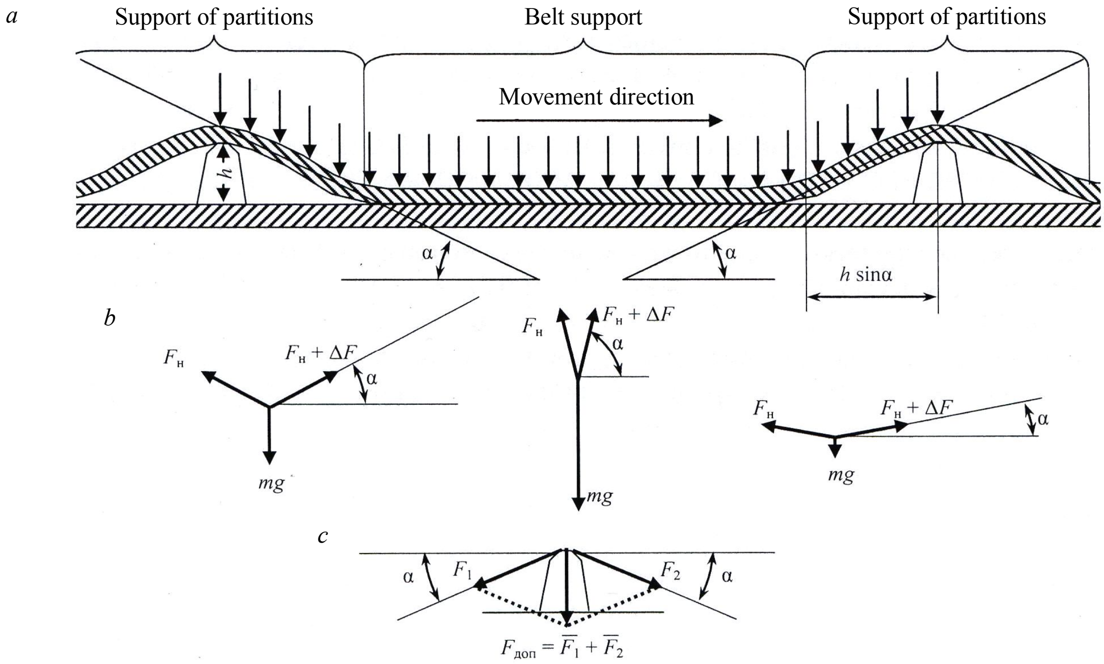

Fig.1. Calculation of tractive ability of drive with cross ridge partitions:
a – general scheme; *b* – angle determination α; *c* – definition of extra traction

When reducing capital and operating costs, this invention will reduce the number of pinch rollers on the lower branch of the drive belt. The reduction in the number and length of intermediate linear drives on the main belt conveyor is possible due to the characteristic features of this linear drive design, which allows for an increase in tractive effort reported to both branches of the conveyor belt.

Figure 1 shows the design diagram of the interaction between the intermediate partitions and the conveyor belt. Part of the belt with the load rests on the intermediate drive belt (Fig.1, *a*), part of the belt – on the partitions; the length of the bearing on the belt and partitions is determined by the angle α, which is created from the tension of the belt and the weight of the load with the belt (Fig.1, *b*). The coefficient of friction of the belt on the partition $f_{\mathrm{p}} = 0.4$, belt on the belt $f = 0.6$.

The increase in tension in the area between the partitions is defined as the friction force:

$$\Delta F = l_b q_{load} \varphi + l_{\mathrm{p}} q_{load} \varphi_{\mathrm{p}} + F_{add}.$$

Additional pressing of the belt is created due to the tension of the belt due to its crowding on the partition (Fig.1, *c*):

$$F_1 = S_{in} + l_b q_{load} \varphi;$$

$$F_2 = F_1 + l_b q_{load} \varphi_p;$$

$$F_{add} = [F_1^2 + F_1^2 - (2F_1F_2\cos(180–2\alpha))]^{0,5}.$$

Discussion. Figure 2 presents the graphs of theoretical dependence. In position 1, the line of the tension relationship is drawn at the point of incident on the linear drive section to the tension when escaping from it. The reduction is due to the fact that when the belt is loaded by the load-carrying branch of the main conveyor, the zone of its contact with the belt of the intermediate linear drive decreases, while the friction zone of one belt over another is replaced by the friction zone of the load-carrying belt of the main conveyor with the partition on the intermediate drive belt with a lower friction coefficient.

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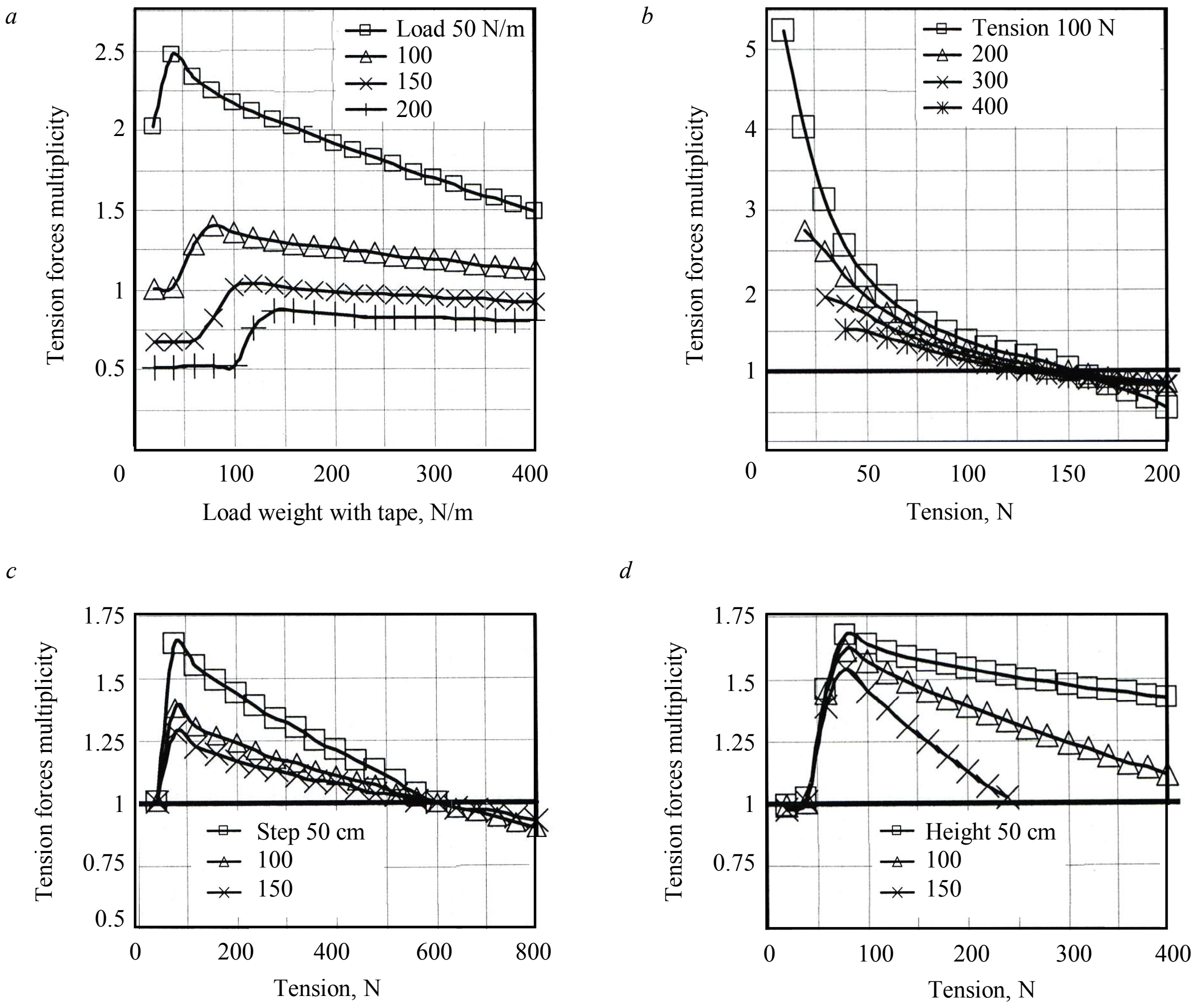

Fig.2. The dependence of the traction ability of the intermediate drive with partitions on the weight of the load on the tape (*a*); the tension of the branch belt (*b*); partition installation steps (*c*); height of partitions (*d*)

The formula for the total amount of traction force implemented by an intermediate linear drive with transverse partitions on the outer surface of the drive belt

$$W = gLf(k\,q + q_1) + 2nT\varphi\sin\alpha,$$

where W – traction force, N; g – gravity acceleration, m/s^2; L – linear drive length, m; k – coefficient taking into account the loading mode of the conveyor belt by the transported cargo; q and q_1 – linear mass of cargo and conveyor belt, kg/m; n – the number of cross ridge partitions mounted on the upper branch of the intermediate drive; T – the average value of the tension of the carrying branch of the conveyor belt in the area of its bearing on the upper branch of the linear drive, N; φ – the value of the friction coefficient of the load-carrying branch of the conveyor belt on the intermediate linear drive belt; α – the average angle of incidence of the conveyor belt on the transverse partitions of the linear drive.

Conclusion. The use of intermediate drives during transportation over long distances allows to increase the length of the conveyor in one level up to several kilometers, while the conveyor belt is characterized by much lower strength and, consequently, cost.

Application at mining enterprises and enterprises of other industries of similar design of linear intermediate drive with partitions will significantly increase traction effort reported by a linear drive conveyor belt, will allow centering the conveyor belt and intermediate drive belt at the same time, as well as expand the possibilities of installing conveyors at different angles of inclination with uneven distribution of the material on the conveyor belt and simplify the process of trapping the belt when it breaks.

The use of such drives does not change the design of the main conveyor equipment; therefore, it is advisable both when designing a new conveyor and reconstructing an existing one.

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