Mathematical model of belt conveyor intermediate drive with baffles

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Abstract. In the modern world, in modern circumstances industries require high-speed technologies and fully automation. The best choice to satisfy these requirements is to implement new technologies with progressive features into transportation processes. This article describes the options for increasing traction of the belt conveyor intermediate drive. The functioning principle of the intermediate linear drive with transverse baffles has been described, formulas for calculating the values of traction effort have been provided, also comparative graphs that show the efficiency of using the intermediate drive in various conditions, have been given.

1. Introduction

Progress in the conveyor construction is moving in the direction of increasing the length of the conveyor in one flight, which makes it possible to significantly reduce costs and slightly improve the reliability of the entire conveyor line [10, 15].

There are many solutions and innovative technologies for solving the problem of high-speed technologies and fully automation in the transportation processes [1-5].

The solution to problems with the conveyor drive is connected with the fact that the traction force is transferred to the belt by friction, which does not exceed a strictly defined and not very large value, which was originally described by Leonard Euler and further supplemented by Zhukovsky I.E.:

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

where $F_{\text{max}}$ – maximum tractive force, N; $S_{\text{sl}}$ – tension of the belt slack side, N; $e^{\mu \alpha}$ – traction factor of the conveyor, $\mu$ – friction coefficient, $\alpha$ – wrap angle.

The maximum possible traction force is rigidly related to two factors: the tension of the belt and the number of drive pulleys, which leads to the need to produce very strong belts [11, 14].

2. Literature studies

During recent years, the demands on mineral transport systems have increased, due to improvements in production rates and extending lengths of conveyor systems. This is particularly appropriate to longwall developments. The requirements associated with these improvements have been identified and as the development of belting technology has enabled higher tensile ratings to be available, the necessary belt conveying equipment to meet these demands also have been developed [19].

When panel lengths were increased, conveyance concerns began to appear. The power and belt strengths needed for these lengths approaching 4 km to 5 km were much larger than had ever been used underground before. Problems included the large size of high power drives not to mention being able to handle and move them around. And, although belting technology could handle the increased strength
requirements, it meant moving to steel reinforced belting that was much heavier and harder to handle and more importantly, required vulcanized splicing [13, 16, 18].

Since longwall panel conveyors are constantly advancing and retreating (getting longer and shorter), miners are always adding or removing rolls of belting from the system. Moreover, since vulcanized splicing takes several times longer to facilitate, lost production time due to belt moves over the course of a complete panel during development and mining would be extreme [8].

The conveyor belt with the intermediate drive is a closed loop load-bearing belt in which there is one or more intermediate linear belt drives in the form of short belt conveyors, and the upper branch of their belt is in force frictional contact with the load-carrying conveyor belt. Each intermediate drive overcomes the resistance of only its own interval section and provides a constant traction ability at the maximum level, which makes it independent of the angle of inclination of the conveyor and causes the reduction of the conveyor's length, technical and economic indicators are significantly improved, and the scope of use of the multidrive belt conveyors expands [2].

The tractive effort is transferred through a conveyor belt by the friction forces generated on the frictional contact surfaces. The frictional surface of the drive pulley is the surface of the pulley, as for linear drive, the frictional surface is the contact area of the conveyor belt with the intermediate drive. Transmitted tractive effort should be sufficient for overcoming resistant forces; however, it should not cause slipping underneath the conveyor belt [21,22].

In contrast to the conventional mode of power transference to the conveyor belt, by wrapping the belt around a single or series of driving pulleys, the booster drive transmits the tractive force linearly, by frictional contact with the main belt. The power-transmitting element is an endless driving belt, which is in contact with the underside of the carrying strand running on the idlers of the main carrying belt [17].

The pressure to transmit the force results from a combination of the weight of the belt and the material being transported. Although the unit pressure is much less than that achieved by the conventional method, an extended length of engagement between the belts attains the required force [7].

The mathematical model of the intermediate linear drive with pressure rollers and the efficiency of linear drive application into the belt conveyor line were presented in previous articles [4-6].

Another type of intermediate linear drive was patented in Saint Petersburg Mining University [1].

3. Methodology
The technical result of the invention is an increase in the traction forces imparted by the linear drive to the load carrying and return strand of the conveyor belt.

The technical result is achieved in that transverse baffles is fixedly attached on the belt outer surface of the intermediate drive in the intermediate linear drive of the belt conveyor with a certain step equal to the step of the trough rollers arrangement. Transverse baffles is made from elastic or rigid material of curvilinear or rectangular transverse profile with rounded upper edges. These baffles consist of three parts – middle and two side parts, which are located with gaps relative to each other with the possibility of ensuring cross bending of the belt when it is supported on the trough rollers of the belt conveyor. The lower belt branch of the intermediate drive is supported by its baffles on the return strand of the conveyor belt.

The intermediate linear drive of the belt conveyor operates as follows. When the drive drum rotates, the tractive effort from the drive belt is transferred to the load carrying branch of the conveyor belt, not only due to the frictional force between them but also due to the persistent interaction of the intermediate drive belt with the load carrying branch of the conveyor belt. This is due to its deflection under the action of its own weight and the weight of the conveyed load placed on the belt between the baffles on the intermediate drive belt, onto which the load-carrying branch of the belt constantly rests. The choice of the material from which the baffles are made and the shape of their cross-section are taken depending on the physical and the mechanical properties of the transported material. Distinctive features of the invention provide a significant increase in traction forces reported by the linear drive both the load-carrying and return branches of the conveyor belt. This allows one to reduce the number of intermediate
linear drives on the main belt conveyor or to reduce their length, and also to reduce the number of pressure rollers on the lower branch of the drive belt, with a corresponding reduction in capital and operating costs [23,24].

The calculating scheme of interaction of the conveyor belt with intermediate baffles is shown in Figure 1.

In the presence of baffles, a part of the belt with the load leans on the baffles, another part of the belt leans on the belt (Figure 1, a). The length of the support on the baffles and the belt is determined by the angle \( \alpha \), which is formed by the ratio of the tension of the belt and the weight of the load with the belt (Figure 1, b).

The friction coefficient of the belt along the belt is accepted \( f = 0.6 \), and the friction coefficient of the belt along the baffle is accepted \( f_b = 0.4 \).

\[
\Delta F = l_{belt} \times q_{load} \times \varphi + l_{baffle} \times q_{load} \times \varphi_{baffle} + F_{add}. \quad (2)
\]

The presence of a striking angle of the belt on the baffle will create additional pressure due to the belt tension (Figure 1, c).

\[
F_1 = S_{start} + l_{belt} \times q_{load} \times \varphi; \quad (3)
\]
\[
F_2 = F_1 + l_{baffle} \times q_{load} \times \varphi_{baffle}; \quad (4)
\]
\[
F_{add} = \left[ F_1^2 + F_2^2 - (2F_1F_2\cos(180-2\alpha)) \right]^{0.5}. \quad (5)
\]

4. Results

The theoretical dependence, determined from these relations, is shown in Figure 2. In Figure 2, for each relationship, a line is made in position 1.0, which corresponds to an equal value of the tension of the run-on to the drive section and the tension when running off the drive section. The decrease below the 1.0 level is due to the fact that when the belt is tensioned, the contact surface of the belt with the belt
decreases, and the belt's friction zone about the belt is increasingly replaced by the zone of friction of the belt about the baffle with a different coefficient of friction (the friction coefficient of the belt along the belt $f = 0.6$, and the friction coefficient of the belt along the baffle $f_b = 0.4$).

Thus, we have a range with reduced efficiency and no application of this type of the drive. The total amount of tractive effort realized by an intermediate linear drive, with transverse baffles on the outer surface of the drive belt, is:

$$W = g L f (k q + q_{belt}) + 2 n T \varphi \sin \alpha,$$

(6)

where $W$ – tractive effort, $N$, $g$ – acceleration of gravity, $m/s^2$, $L$ – intermediate drive length, $m$, $k$ – coefficient that takes into account the loading of the conveyor belt by the transported load, the value of which is equal to one, with continuous supply of material to the conveyor belt, or less than one, for
temporary interruptions in the delivery of material, \( q \) and \( q_{\text{belt}} \) – linear mass of transported material and conveyor belt, \( \text{kg/m} \), \( n \) – amount of transverse baffles fixed on the upper branch of the linear drive, \( T \) – the average value of the conveyor belt load-carrying branch tension in the area of its support on the upper branch of the linear drive, \( N \), \( \varphi \) – the value of the coefficient of friction between the load-carrying branch of the conveyor belt and the linear drive belt, \( \alpha \) – the average value of the angle of the conveyor belt on the transverse baffles of the linear drive along its entire length.

5. Conclusion
Application of intermediate drives will make it possible to reduce the cost of the belt, increase reliability, and reduce the operating costs of the conveyor.

The use of intermediate drives allows increasing the length of the conveyors in one flight up to several kilometers, using a low-strength conveyor belt of much lower cost.

The use of the proposed linear drive design at mining plants and enterprises of other industries will significantly increase the tractive effort reported by the linear drive to the conveyor belt, with simultaneous centering of the conveyor belt and the drive belt. This will expand the possibilities of using conveyors at different angles of inclination and conveyor line profiles in including limited length of adjacent sections of the conveyor with different angles of inclination and with an uneven distribution of the transported material along the conveyor line, facilitates the process of catching the broken belt of the inclined conveyor.

In this case, the use of the drive is possible not only in the design of the conveyor, but also in its reconstruction, since the introduction of the proposed technical solution is not associated with a change in the design of the main conveyor equipment.

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