Theoretical study of influence of belt tension of intermediate belt conveyor drive on value of zone of relative slip of traction and carrying belts

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Theoretical study of influence of belt tension of intermediate belt conveyor drive on value of zone of relative slip of traction and carrying belts

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Abstract. The issue of the influence of tension of the traction belt of intermediate drive of the multi-drive belt conveyor on the value of zones of relative rest and sliding of the traction and carrying belts is considered. A variety of values of proportional band of tractive effort regulation of the intermediate drive of belt conveyor while it is being controlled by the tensioning device was obtained in percentage terms. Recommendations on the control of the intermediate drive of belt conveyor by means of the tensioning device when starting and productivity changes are provided.

1. Introduction

The modern development of the mining industry requires increased attention to the state and prospects of the development of conveyor transport [7], including the movement of goods over significant distances along a complex route, often without the possibility of intermediate transshipment. To accomplish this task, conveyors equipped with drive systems, including two or more drives, are widely used. One of the most widely used solutions in the design of belt conveyors is the use in their design of traction belt circuit as an intermediate drive.

When the traction force is transferred from the traction belt to the load-bearing one, zones of relative rest and slip are formed in the area of their contact. The process of formation of these zones is described in [1, 8]. In the zone of relative slippage, the traction is transferred to the load-carrying belt. As the length of this zone increases, the traction force realized by the drive increases. When the zone of relative rest decreases to zero value, the clutch disengages, and the drive slips.

To determine the lengths of zones of relative rest and slip of belts, several different approaches are used, considered in [1, 3, 6, 9]. The most precise method is the one proposed in [3], which differs from the methods proposed in [6, 9] by the following features: 1) small values of changes in the speeds of belts are taken into account, the account of which has a significant effect on the distribution of traction forces between drives; 2) the resistance to the motion of belts is given taking into account their separation into resistances, which depend on the tension of belts and which do not depend on them; 3) mechanical characteristics of electric motors of drives are taken into account in the form of nonlinear functions. The method proposed in [1] is based on the determination of values of zones of relative rest and slip, on the basis of the magnitude of the driving force of drive, as specified by the designer.

Recently, in the design of belt conveyors, drives with a frequency conversion control system [8] are
increasingly being used, which increases the cost of the drive on the one hand, and, on the other hand, allows the driving force to be controlled in a relatively wide range. In the case of an uncontrolled drive, the ability to control the traction forces of intermediate belt drives is limited by the possibilities of their tensioning devices. In this paper, we present the results of a theoretical study of the effect of pulling the traction belt of an intermediate belt conveyor drive on the change in the values of zones of relative rest and sliding of traction and carrying belts.

2. Method description
When constructing mathematical models for the operation of a belt conveyor, various methods of taking into account deformation of the belt are used [10]. So in [5] the conveyor belt is counted as a set of closed point masses connected by spring-damper bonds, and in [1, 3] the conveyor belt is represented as an ideally extensible flexible thread.

The method for determining the zones of relative rest \( l_{rr} \) and slip \( l_{rs} \) is based on taking into account mechanical characteristics of the drive systems by expressing traction forces of intermediate drives through the pulling force of the main drive taking into account the longitudinal stretching of belts [3]. To determine the length of the relative slip zone of belts, we use the mathematical model formed in [3], which includes general equation of traction calculation, equations describing mechanical characteristics of drives, the equation relating rotational speeds of drums, and equations describing the absence of slippage of belts on drums.

To carry out studies of the effect of belt tension of the intermediate belt drive on the value of the relative slip zone of belts, we use an example of a conveyor described in [3], having the following parameters: productivity \( Q = 300 \text{ t/h} \), length of the horizontal projection of the route 1000 m, length of the intermediate belt drive \( l_{in,d} = 200 \text{ m} \); as a carrier and traction tapes, the standard rubber-fabric tape 2SHTK200-2 × 3 with a tensile stiffness \( E_c = E_T = 3.2 \text{ MN} \) is used, it should be noted that the type of belt affects the performance of the conveyor described in [2], the mechanical characteristics of drives are identical, the tension of the load-carrying belt is constant \( S_{b1} = 20000 \text{ N} \). The layout of the conveyor route is shown in Fig. 1.

![Figure 1. Scheme of the conveyor route for research](image)

When carrying out the research, as the variable parameters, we take the belt tension at the run-off point from the drive drum of the intermediate drive \( S_{b2} = 16000 \ldots 40000 \text{ N} \) (it is created and maintained by the adjustable tensioning device) and the productivity of the conveyor \( Q = 0 \ldots 300 \text{ t/h} \).

Calculating the size of the zone of relative slip of traction and carrying belts with a step capacity of \( Q = 50 \text{ t/h} \) with an increase in the tension of the traction belt, we obtain the graph shown in Fig. 2.

This graph (Fig. 2) reflects the values of the change in the length of the zone of relative slippage of traction and load-bearing belts with an increase in the productivity of the conveyor and a change in the tension of the traction belt within the specified limits for each value of productivity. Thus, at zero conveyor capacity (empty conveyor belt) with increasing in belt tension of the intermediate traction drive, the length of the relative slip zone is reduced by 11.85 m (7.59 %) compared to its original
length of 156 m, which makes it possible to regulate traction drive force within the limits fold to a specified percentage.

Increasing the productivity of the conveyor to $Q = 50 \, \text{t/h}$, a decrease in the length of the zone of relative slip of belts to 120.4 m is observed (Fig. 2). As tension of the traction belt increases, the length of the investigated zone decreases, reaching 6.68 m (5.6 %). In this case, the possibility of adjusting the tractive force is reduced in comparison with the idle speed and is within limits fold to the specified percentage.

![Figure 2. The graph of the change in the length of the zone of relative slip of the belt with increasing productivity of the conveyor](image)

Increasing the conveyor capacity to $Q = 100 \, \text{t/h}$ decreases the length of the zone of relative slip of belts with the initial tension of the traction belt to 94.63 m. The increase in tension of the traction belt of the intermediate drive to $S_{b2} = 40000 \, \text{N}$ shortens the length of the zone by 4.65 m (4.92 %), creating the possibility of regulating the tractive effort within limits fold to 4.92 %. When comparing this percentage with the results obtained earlier, it can be concluded that with increasing productivity, the influence of belt tension of the intermediate drive on the possibility of regulating traction is observed.

With a conveyor capacity of $Q = 150 \, \text{t/h}$ and an initial tension of the belt, the length of the zone of relative slip of belts is 80.89 m. Increasing in the tension of the traction belt reduces the length of the rest zone by 3.57 m (4.41 %), which in its turn allows to adjust the driving force of the drive within a range that is fold of 4.41 %. Comparing the obtained value with the previous data, the tendency of decreasing the possibility of the effect of adjusting the tension of the belt of the intermediate drive on the traction force perceived by it is also seen.

Calculating the length of the zone of relative slip of belts, with the productivity of the conveyor $Q = 200 \, \text{t/h}$, we obtain a decrease in its length to 72.38 m, but an increase in tension of the traction belt reduces the obtained value by 2.9 m. In percentage terms, this change is 4 %, while the possibility of adjusting the tractive effort of the drive falls in comparison with previous calculation cases.

After increasing the productivity of the conveyor to $Q = 250 \, \text{t/h}$ under the schedule (Figure 2), it is seen that the length of the zone of relative slip of belts decreases to 66.61 m, the increase in tension
of the traction belt changes its length by 2.44 m (3.66 %), while the obtained traction control capability, fold of 3.66 %, is lower in comparison with the calculated situations given above.

As the conveyor has a maximum capacity of $Q = 300$ t / h, the value of the zone of relative slip of belts is 62.45 m as seen from the graph (Fig. 2). With increasing in tension of the traction belt, its initial value decreases by 2.11 m that in percentage terms is 3.37%. The possibility of regulating the tractive effort in comparison with the empty conveyor decreases almost twofold and is fold of the obtained percentage.

Based on the above data, it is possible to generate a plot of the relative range of traction control of the drive from the performance of the conveyor.

![Graph of change in the relative range of traction control of the drive from the performance of the conveyor](image)

Figure 3. Graph of change in the relative range of traction control of the drive from the performance of the conveyor

3. Conclusion

The results of a theoretical study of the influence of the belt tension of the intermediate drive on the changes in the zone of relative slip of traction and load-bearing belts show that when the tension of the traction belt is changed, it is possible to regulate the traction of the drive, in relative units, sufficient to stabilize the uniformity of the distribution of tractive forces between drives in terms of possible deviations of their mechanical characteristics, the negative effect of which is described in [4]. However, with the increase in the productivity of the conveyor, this possibility is significantly reduced. As it can be seen from the graph (Fig. 3), in the current example, when operating in idle mode, the relative control range reaches a fold of 7.59 %, but at a capacity of $Q = 300$ t / h decreases to 3.37 %.

On the basis of the conducted researches, it is possible to formulate the following key moments that determine the regulation of the value of tractive effort created by the intermediate belt drive, by its tensioning device:

- when starting an empty conveyor (idling), the tension of the belt of intermediate drive is it desirably to minimize, which contributes to a more even distribution of tractive effort between the intermediate drive and the head drive;
- in the process of loading the conveyor to the maximum value of its productivity, the redistribution of the traction forces of conveyor drives can be carried out by adjusting the mechanical characteristics of motors. In this regard, and also taking into account the fact that with the increase in
productivity, the effect of the change in belt tension of the intermediate drive on its traction characteristics is significantly reduced (Figure 3), the tension of the intermediate drive belt can be increased to the design value.

To develop a more comprehensive set of recommendations, additional studies should be carried out separately on the effect of the variation in the tension of carrying belt, and also on the traction and weight-carrying belts together on the possibility of regulating the traction of drives.

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