Innovative Engineering Design of the High-Angle Conveyor for Mining of Deep-Seated Mineral Deposits

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Introduction

The development of open pit mines is accompanied by an increase in the depth of quarries, changes in mining and geological and mining conditions. Ensuring further increase in production of large quarries depends on the correct choice of flexible technological schemes of development and mining equipment, the most adapted to the internal infrastructure. The use of a steep belt conveyor in these conditions will improve the efficiency of the systems of cyclic-flow technology (CFT).

In comparison with traditional conveyors, inclined conveyors are able to move bulk materials at an angle of 50-60° or more. This allows to significantly reduce the amount of mining and capital work in the preparation of the lift route on Board the quarry. The influence of the angle of its slope and the height of the rise of the rock mass can be traced according to the specific capital and operating costs for crushing and conveyor complexes (CCC) with an annual volume of traffic of 20 million tons (Figure 1) [1]. From Figure 1 it can be seen that the difference in costs, especially operating costs, for crushing and conveyor systems with the slope angles of the conveyor lift route 18° and 60° is not very large at the height of the material lifting up to 100-200m. It becomes noticeable when the material rises above 200m.

Reduction of costs for the crushing and conveyor complex with a slope angle of the lift route 60° in comparison with the complexes in which the conveyor lift is installed at an angle of 18° is shown in Figure 2. The results show that the use of steeply inclined conveyor lifts are useful to consider when the lifting height of the mountain masses of more than 100-150m. This applies to mining conditions, the use of both traditional and steeply inclined conveyors. In other circumstances, the use of steeply inclined conveyors will be more justified when the height of the material lifting is over 200m.
conditions of quarries, when it is very difficult to place traditional conveyors without large volumes of mining and capital works, the use of steep ones does not raise doubts practically from the depth of transition to combined transport.

**Figure 1**: Change of specific capital and operating costs for crushing and conveyor complexes depending on the hoisting height of the rock mass and the angle of inclination of the conveyor elevator: inclination angle of the conveyor (β), height of material hoisting (hₚ), specific capital (Кₚ) and operating (Эₚ) costs.

**Figure 2**:

**Current status of the issue**

The use of steeply inclined conveyor systems can significantly improve the efficiency of motor and conveyor transport. Domestic and foreign organizations and manufacturers have developed a large number of steeply inclined conveyors for various operating conditions. There are steeply inclined belt conveyors with corrugated belts, providing lifting of cargo at an angle of up to

27°, with transverse partitions and corrugated side walls, with transverse partitions without side boards, belt-bucket type (lifting angle up to 30°), tubular type (lifting angle up to 30-50°). The use of plate conveyors with partitions for the steep lifting of the rock mass from the quarries is considered. It is proposed to use a conveyor belt and chain type with retaining partitions without bottoms. In this case, the conveyor belt is a load-bearing, moves due to the friction forces with the transported material and partitions, which are driven by a traction-driven chain circuit [2].

The experience of operation of continuous-action units with traction chain circuits (plate and scraper conveyors, bucket elevators, etc.) shows that due to the low reliability and durability of chain traction bodies, such designs practically do not meet the requirements for the equipment of career conveyor transport. This fully applies to the conveyor belt and chain type.

In deep pits for transporting lumpy rock mass preferred dual belt conveyors with a pressure (transshipments) ribbons (tilt angle up to 25-30) and additional pressing gruzoperevalki tapes mechanical devices located stationary in the linear part of the conveyor (elevation angle more than 30°) [3,4]. The design of the linear rate of this type of conveyor is shown in Figure 3. Double-circuit belt conveyors with mechanical clamping devices of load-holding belts have found quite wide application abroad and are beginning to be implemented in the complexes of the CFT in Russia and CIS countries.

Figure 3: The design of the linear frame of double-circuit belt conveyor with clamping (load-holding) belts: a) with two clamping rollers; b) with three clamping rollers; 1—supporting metal construction; 2—load-carrying contour belt; 3—roller support; 4—load-holding contour belt; 5—clamping elements with rollers.

In Russia, the steeply inclined conveyor with a clamping belt is mounted in Olenegorsky [5,6]. One of the most powerful conveyors is mounted on the quarry of Muruntau of Navoi GOK (Uzbekistan) [7,8]. It is manufactured by Novo-Kramatorsk machine building plant (NKMZ, Ukraine). Less powerful steeply inclined conveyor operated at the mine “Maidanek” (Yugoslavia) until 1996 [9]. Technical characteristics of these conveyors are given in Table 1.

Table 1: Key specifications of high-angle conveyors.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>«Muruntau»</th>
<th>«Maidanek»</th>
<th>«Olenegorsky»</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transported material</td>
<td>Gold ore</td>
<td>Copper ore</td>
<td>Iron ore</td>
</tr>
<tr>
<td>The performance of the conveyor, t/h</td>
<td>3460</td>
<td>2000</td>
<td>1200</td>
</tr>
<tr>
<td>Conveyor length, m</td>
<td>-</td>
<td>-</td>
<td>252</td>
</tr>
<tr>
<td>The bulk weight of the transported material, t/m3</td>
<td>1,73</td>
<td>2,08</td>
<td>-</td>
</tr>
<tr>
<td>The maximum size of the transported material, mm</td>
<td>350</td>
<td>250</td>
<td>80</td>
</tr>
<tr>
<td>Belt width, mm</td>
<td>2000</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Belt speed, m/s</td>
<td>3,5</td>
<td>2,8</td>
<td>-</td>
</tr>
</tbody>
</table>
Corrugations are made of resilient-elastic material, have good damping ability and restore their shape after the disappearance of contact with the transported material. The maximum height of the corrugation corresponds to the depth of the gutter of the load-bearing tape, and in the absence of rock mass on it, the corrugation enters its gutter and performs the function of a partition.

To increase the holding effect, it is advisable to increase the area of contact of the corrugation with the transported material. This can be achieved by flattenings the surface of a rock mass in the chute load-carrying belt. Modeling in laboratory conditions was tested the method of levelings of rock mass by increasing the angle of inclination of the side rollers in frame linear of conveyor after a section of the load. Experimental studies of the state of the load during the movement of the load-bearing belt found that the increase in the angle of inclination of the side rollers gives positive results of the formation of a flat (horizontal) surface of a coarse rock mass in the trough of the tape.

The performed calculations showed that, with a width of the load-bearing belt of 1.4m, the installation of side rollers in the roller supports of the loading point at an angle of 30° and the angle of slope of the transported material in the chute of the load-bearing belt 15° the maximum angle of installation of the side rollers in the 48°.

In addition to increasing the contact surface of the clamping elements in the form of corrugation with the transported material, the installation of a linear footing roller carriage with a large angle of inclination of the side roller carriage the friction force of the rock mass with the load-bearing belt due to the effect of deep grooving.

The design features of the steeply inclined belt conveyor with moving clamping elements in the form of corrugation provide a reliable rise of uneven flow of rock mass due to: the joint use of forced pressing of the transported material in the chute of the load-bearing tape and the effect of deep groove; synchronous with the load-bearing belt movement of clamping elements; elastic properties of clamping elements, allowing them to perform the additional function of backing the transported material. The section of the linear rate and its cross section are shown in Figure 4, and the principal execution of the belt load-carrying circuit-in Figure 4.

### Table 2: Capability of the special high-angle conveyors NKMZ.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value of Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting height of the transported material, m</td>
<td>270</td>
</tr>
<tr>
<td>Conveyor installation angle, deg.</td>
<td>37</td>
</tr>
</tbody>
</table>

The question of application of steeply inclined conveyor lifts with capacity of 3000-3500t/h on Kovdorsky GOK (Russia) (height of lifting of material of 140m) is considered; Central GOK (Ukraine) (height of lifting of material of 175m). The intended manufacturer is NKMZ. In addition to these NKMZ manufactures special steeply-inclined conveyors (Table 2). Other machine-building plants of the CIS countries do not produce powerful steeply inclined conveyors.

Analysis of the embodiment and transportation process of coarse rock mass by two-circuit steeply inclined conveyors with stationary damping devices revealed their significant drawbacks:

A. Permanently installed clamping devices of the load-carrying belt create the prerequisites for the movement of the transported material between them in the direction of the tail of the conveyor with uneven loading of the belt. This phenomenon reduces the reliability and safety of the conveyor;

B. Dynamic loads arising during the interaction of clamping devices with pieces of transported material significantly increase its movement, which significantly increases the wear of the working surfaces of conveyor belts;

C. Reduction of the receiving capacity of the load-carrying tape to 15-20% due to the use of its side bands with a width of about 200-250mm for pressing the load-carrying tape with side rollers.

D. These disadvantages can be eliminated by using clamping elements that have the ability to move together with the transported material and pressing the load regardless of the height of its location in the chute of the load-bearing belt.

### Research Result

As a result of the analysis of the structures of steeply inclined conveyors by the employees of IGD Uro RAS, a schematic diagram of a two-circuit steeply inclined conveyor with moving clamping elements was developed [10]. A feature of the design is the performance of clamping elements in the form of corrugations fixed to the outer (working) surface of the belt of the load-holding circuit. Corrugations are made of resilient-elastic material, have good damping ability and restore their shape after the disappearance of contact with the transported material.
Based on the principles of safe holding large lump rock mass in the load-carrying belt chute steeply inclined conveyor with a moving damping elements, Mining Institute UB RAS:

A. The main provisions of calculation of its main parameters are developed;

B. The interaction of clamping elements (corrugation) with the transported material is investigated and the dependences of the change in clamping force on their main parameters (height and thickness of the cross section) at different conveyor performance are established;

C. The distance between adjacent corrugations based on the theory of stability of the rods, determined by the balance of forces, rolling the load in the direction of the tail of the conveyor, and the friction forces between the rock mass and compressing its surfaces of the corrugation and the load-bearing belt is justified;

D. The economic and mathematical model of calculation of parameters of steep conveyors of this type and the cost of transportation of rock mass. This allowed to prove the feasibility of using pipelines in the systems of the CFT with the automobile-conveyor transport (Figure 5).

Figure 4: The linear frame of high-angle conveyor (design of the Institute of Mining UB RAS) 1-load-holding belt with corrugations; 2-transported material.

Figure 5: Principal engineering design of the load-holding circuit belt: 1-flat carrying belt; 2-corrugated belt; 3-affixing of the corrugated belt to the carrying belt.
Technical and economic evaluation of the effectiveness of the use of steeply inclined double-circuit conveyor with moving elements in comparison with other types of conveyors is carried out for the conditions of the career of Kachar CFT (Table 3).

**Table 3:** Indicators of application of conveyor transport of rock mass in the career of Kachar MSP (H=120m, Q=21 million tons/year).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Single-Circuit Belt</th>
<th>Double-Circuit Belt</th>
<th>Double-Circuit Belt with Moving Clamping Elements</th>
<th>Lamellar Double-Circuit with Partitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyor installation angle, deg.</td>
<td>16</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Length of the inclined part of the conveyor, m</td>
<td>435</td>
<td>210</td>
<td>210</td>
<td>2 × 210</td>
</tr>
<tr>
<td>Belt width, m</td>
<td>1,6</td>
<td>2,0</td>
<td>2,0</td>
<td>2 × 1,4</td>
</tr>
<tr>
<td>Load-carrying circuit</td>
<td>-</td>
<td>-</td>
<td>1,6</td>
<td>-</td>
</tr>
<tr>
<td>Load-holding circuit</td>
<td>-</td>
<td>-</td>
<td>1,6</td>
<td>-</td>
</tr>
<tr>
<td>Drive power, kW</td>
<td>3000</td>
<td>2890</td>
<td>2880</td>
<td>2 × 1520</td>
</tr>
<tr>
<td>The weight of the conveyor, t</td>
<td>435</td>
<td>450</td>
<td>393</td>
<td>2 × 354</td>
</tr>
<tr>
<td>Capital expenditure, %</td>
<td>100</td>
<td>104</td>
<td>84</td>
<td>160</td>
</tr>
<tr>
<td>Operating costs, %</td>
<td>100</td>
<td>107</td>
<td>93</td>
<td>166</td>
</tr>
</tbody>
</table>

Summary

As a result of the research, the theoretical foundations and practical prerequisites for the development of design documentation for the creation of steep conveyor lifts with moving synchronously with the belt clamping elements in the form of elastic corrugations are created.

A schematic diagram of a two-circuit steeply inclined belt conveyor with moving clamping elements is developed. A feature of the design is the performance of clamping elements in the form of corrugations fixed to the outer (working) surface of the belt of the load-holding circuit. Corrugations are made of elastic-elastic material (for example, conveyor belt), have good damping ability and restore their shape after the disappearance of contact with the transported material. The maximum height of the corrugation corresponds to the depth of the gutter of the load-bearing tape, and in the absence of rock mass on it, the corrugation enters its gutter and performs the function of a partition. The conveyor design is protected by the RF patent.

The design features of the steeply inclined belt conveyor with moving clamping elements in the form of corrugation, provide a reliable rise of uneven flow of rock mass due to the joint use of forced pressing of the transported material in the chute of the load-bearing tape and the effect of deep groove; synchronous with the load-bearing tape movement of clamping elements, elastic properties of clamping elements, allowing them to perform the function of additional support of the transport material.

The use of steeply inclined conveyors with moving clamping elements can significantly increase the completeness of the technical capabilities of the equipment. So its coefficient of use of technical capabilities, determined by the product of the coefficients of the use of equipment in time and performance, has a value of 0.56-0.6, which is almost twice as high as this indicator of the steeply inclined conveyor with stationary clamping elements in the form of rollers (0.27-0.29), installed at the quarry of Muruntau Navoi GOK [5] (Uzbekistan).

It is established that at the annual performance of complexes 5-0 million tons steeply inclined conveyors should be used in the heights of the rock mass over 100-200m. Under these conditions, at a lower operating cost (5-20%) specific capital costs for complexes, steeply inclined conveyors significantly (13-30%) lower. In addition, the use of steeply inclined conveyors is preferable in terms of labor productivity per worker of the CFT complex (higher by 8-20%). With the increase in productivity of the CFT complexes to 20-30 million. CFT steeply inclined conveyors should be used for lift heights of rock mass, more than 200-300m. under these conditions a small difference in the specific operating costs (less than 10%), capital costs for complexes of CFT with steeply inclined conveyors below 10-22% [11,12].

References

5. Olenegorsk GOK launched a crushing complex in a quarry with the KNK [Electronic resource]: access Mode.


