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# SUBSTANTIATION OF PARAMETERS AND EFFICIENCY OF SANDWICH BELT HIGH ANGLE CONVEYORS FOR DEEP OPEN PIT MINES

*The article focuses on substantiation of such parameters of heavy-duty sandwich belt high angle conveyors as the belt width to ensure operation without spillage of load, and the hugging pressure with regard to its dependence on the angle and length of the conveyor. It is noted that incorrect estimation of these parameters can lead to the redistribution of forces between the conveying and hugging belts with increasing load applied on the conveying belt.*

*The economic efficiency of the high angle conveyors is considered in comparison to the traditional belt conveyors. It is shown that the cost of a traditional belt conveyor jumps with the increasing height of hoist. It is shown that the operating costs of the sandwich belt high angle conveyors increase almost linearly with an increase in the hoisting height and very slightly depend on the conveyor angle.*

***Keywords:*** *sandwich belt high angle conveyors, productivity, hugging pressure, belt width, spillage, installation angle, investment index*
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### Introduction

The Russian opencast mineral mining industry produces more than 90% of iron ore, 70% of nonferrous metals and 60% of coal. Production output mostly grows in large opencast mines, which, naturally, governs the increase in their depth and size. The cost of mineral haulage reaches 60% of total opencast mining expenditures.

In these conditions, it is highly critical to create and improve work equipment for transportation of minerals and overburden rocks. The internationally common transition to the cyclical-and-continuous technology in opencast mining has decreased the automobile transport load and cost for some time, despite the heavier expenditures connected with crushing and rehandling.

As the depth of opencast mines grows, so does the cost of installation of conventional belt elevators (belt conveyors) at an angle of 14–16°, which requires cutting a trough or a semi-trough.

A sufficiently deep open pit (depth more than 400 m) may need not one conveyor but a conveyor line composed of 3 or 4 (or more) conveyors to be installed, which increases their total estimated output. Considering a conveyor as a system with finite time of performability recovery and assuming that all conveyors in the line stop if some component of some conveyor fails, the belt conveyor availability factor may range as 0.970–0.980 subject to design of the conveyor assemblies and depending on installation site. In this respect, a system of 4 series-connected conveyors, even without regard to the presence of re-loading points and some associate elements, has the availability factor of 0.742–0.801 [1]. Moreover, this involves extra stripping and the elevated capital cost.

In this case, an alternative to a belt conveyor can be special conveyor types with a higher factor of friction between the belt and cargo, with a deeper trough, with corrugated walls and partitions. Furthermore, these conveyors may be tubular belt conveyors and sandwich belt high angle conveyors [2].

### Main part

A sandwich belt high angle conveyor (hereinafter, HAC) composed of conventional time-tested assemblies, including traction members with smooth surfaces, which facilitates clearing and, thus, conditions economy and lower operation and maintenance costs, has an almost unlimited conveying capacity (**Fig. 1**).

HAC has two conveying loops—load-carrying and load-hugging, and each loop has its own drive and a pulley. The pull is implemented by both loops, which allows using belts having lower strength, and also total length of the belts involved is shorter than ordinary belt conveyors have to lift cargo to the same height. For another thing, the stone drivage amount reduces greatly with HAC.

At the same time, HAC have a more complex structure and a higher metal consumption.

At the moment, HAC have positively proven their effectiveness and are operating reliably both in Russia and abroad, including the former USSR countries.

As a rule, operating conveyors of this type have comparatively small heights and lengths of haulage. Russian open pits have already reached the depth of 400 m and now need high-duty HAC more than 150 m long, with conveying capacity of 2000–4000 t/h

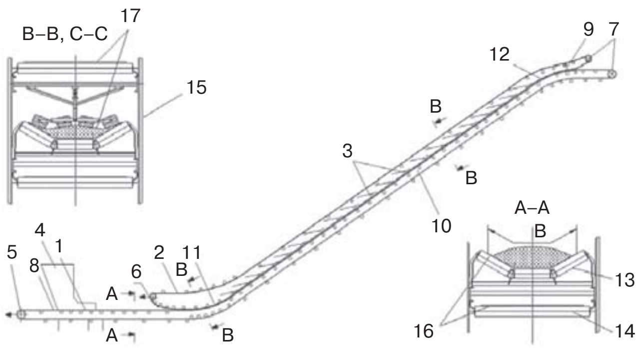


**Fig. 1. Sandwich belt high angle conveyor:**
1—load-carrying belt; 2—hugging belt; 3—pressers; 4—loading facility; 5—load-carrying belt tensioner; 6—hugging belt tensioner; 7—drives of load-carrying and hugging belts; 6—loading area; 9—transition of cargo from high-angle to flat branch; 10—high-angle branch; 11—bottom transition site; 12—top transition site; 13 and 14—top and bottom roller carriages of load-carrying belt; 15—metal framework; 16—upper and lower branches of load-carrying belt; 17—upper and lower branches of hugging belt

**Table 1. Heavy-duty high angle belt conveyors in operation in open pit mines in the world**

| Open pit mine, company, conveyor installation year | Cargo | Bulk density, $t/m^3$ | Capacity, t/h | Elevation angle, deg | Elevation height, m | Length, m | Belt width, mm | Belt velocity, mm | Motor capacity, kW | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Hugging | Conveying |
| Triton Coal Co, Wyoming, USA | Coal | 0.95 | 2540 | 60 | 32.9 | 56.7 | 1524 | 5.33 | 149 | 224 |
| Majdanpek, Serbia | Copper ore | 2.08 | 4000 | 35,5 | 93.5 | 173.7 | 2000 | 2.67 | 450 | 900 |
| Turris Coal Co, Wyoming, USA, 1993 | Coal | 0.88 | 1361 | 90 | 102.0 | 113.0 | 1524 | 4.57 | 298 | 298 |
| Perini, Massachusetts, USA, 1993 | Sandstone rocks | 1.1–1.3 | 1266 | 90 | 70.1 | 83.8 | 1372 | 3.56 | 186 | 186 |
| Muruntau, Uzbekistan, 2011 | Gold ore | 1.75 | 3500 | 37 | 270.0 | 960.0 | 2000 | 3.15 | 1260 | 3780 |
| Olenegorsk, Olkon JSC, Russia, 2015 | Iron ore | 1.9–2.2 | 1200 | 36 | 124.0 | 315.0 | 1600 | 2.90 | 110 | 710 |
| Mikhailovsky GOK, Russia, 2020 | Iron ore | 2.2 | 3000 | 37 | 215.0 | 700.0 | No data | No data | No data | No data |

and higher, and with the elevation angles of 30–55° [3]. The largest HAC operating in open pit mines in the world are described in **Table 1**.

Evidently, heavy-duty and long high angle conveyors have specific design and operation variables. Technical literature contains many studies into the energy intensity of such conveyors, the required hugging pressure, economic efficiency of operation, etc., which adjust and amend design techniques of such machines.

The economic efficiency can be illustrated by operation of such conveyor put into service in Muruntau open pit mine in Uzbekistan in 2011 (this conveyor has a record capacity and elevation height): 2012 saving totaled USD 2.7 million owing to the reduced cost connected with operation and maintenance of dump trucks (lubricants, fuel, spare parts etc.) [4].

The ample research of HAC performance implemented at the Institute of Mining, UB RAS shows that efficiency of the cyclical-and-continuous technology with HAC has some minor limitations as compared with the standard belt conveyors [5].

Foreign researchers also pay attention to this issue [6–8]. The research work by Dos Santos J. D seems to be of the highest interest [6] as it compares investment (design and delivery) in four conveying scenarios: belt conveyor at an angle of 15° and HAC in case of three different angles of 45°, 60° and 90° with elevation to the hoists of 20.8, 32.5, 44.4, 60.2 and 76 m (**Fig. 2**). The analysis only includes the cost of the machine components. The costs of packaging, spatial orientation, or, for instance, placement of a conveyor on the bench slope, etc. are disregarded.

It is seen in Fig. 2 that the standard belt conveyor has a lesser cost of hoisting to the smallest (out of the selected values) height. The cost jumps with increasing elevation height and exceeds the hoist cost of HAC at the elevation height of 33 m. At the maximum hoisting height of 76 m, the expenditures connected with HAC operation are less than with the conventional belt by 60–88% subject to the conveyor installation angle.

The costs of HAC increase gradually with the growing hoisting height and insignificantly depends on the hoisting angle. For example, at the smallest height at the angle of 45°, HAC investment index is 0.23 as against 0.24 (higher by 4%) at the hoist angle of 60° and 0.27 (higher by 17%) at the angle of 90°. Vertical HAC have the lowest investment index of 0.51 as against 0.56 (higher by 10%) at the angle of $60^0$ and 0.60 (higher by 18%) at the angle of $45^0$.

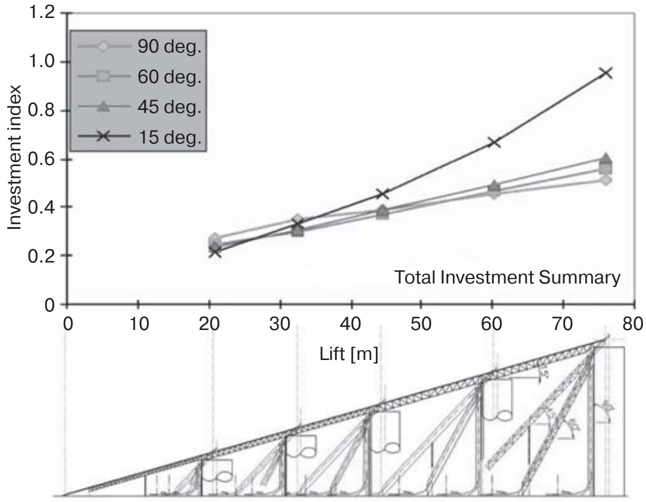


**Fig. 2. Investment index of diffeent belt conveyors versus elevation angle and height**

The calculations performed at the NUST MISIS' College of Mining for the heavy-duty conveyors in conveying to the height of 200–270 m at the production capacity of 2500–3500 t/h also proved efficiency of HAC installed at the angles of 35–45° as compared with the conventional belt conveyors. Furthermore, it is found that the power input of HAC is independent of the installation angle. **Figure 3** depicts the HAC power input and length as function of its angle at the hoisting height of 270 m.

Figure 3 shows that the standard belt conveyor set at the angle of 15° has lower installed capacity by 18.5% at the length longer by 48–74%.

The comparison of the two conveyor types should take into account that the selection and calculation of parameters for both generally coincide but the construction of HAC differs, which is important in design and justification of HAC performance in specific operating conditions.

First, HAC has a much larger cross size of the belt. The model of the cargo load on the belt of HAC is presented in **Fig. 4**. The area occupied by cargo is smaller as it is required to isolate the material between the belt and, moreover, to minimize displacement of the belt edges to avoid spill of the material being conveyed.

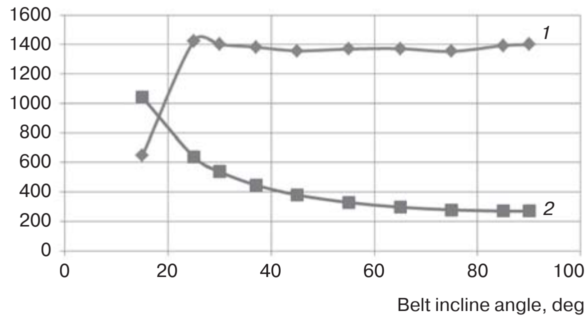


**Fig. 3. Power input of high angle conveyors having capacity of 3500 t/h versus hoisting length and angle in elevation to the height of 270 m:**
*1*—power input +3000 kW; *2*—high-angle branch length, m

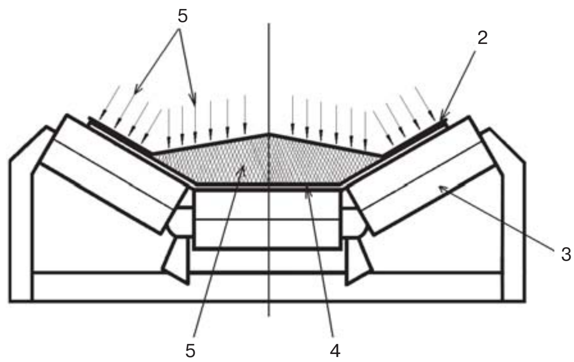


**Fig. 4. Cross-sectional view of high angle conveyor:**
1—hugging pressure; 2—hugging belt; 3—roller carriage; 2—conveying belt; 5–cargo being conveyed

The cross-sectional view in Fig. 4 demonstrates that only some portion of the hugging pressure is transferred to cargo, which should be taken into account in the hugging pressure calculus.

Inspection of the operating large conveyor systems shows that their load-carrying (conveying) belt 1.4–2 times wider than the ordinary conveyor belt at the same capacity and belt speed. This increases the cost of the belts but their total length can be decreased by increasing the angle of the conveyor installation. At the HAC angle from 33° and higher, the belt lengths are smaller than the conventional belt set at the angle of 15° has, which somewhat levels down the anticipated expenses.

Second, the required pressure of the hugging belt of the high angle conveyor grows essentially at the hoisting height of 100 m, and the rate of the growth is higher with the higher angle of the conveyor (**Fig. 5**) [9–11].

Third, the metal consumption of the conventional belt conveyor is smaller (by 65–70%) as compared with HAC which includes auxiliary structural components (supports, rollers of the unladen branch of the hugging belt, pressers, transition areas of the hugging loop) [12].

At the same time, the standard belt is 1.7–5 times longer than HAC, or even 2.0–2.5 times at the pitwall slope from 30° to 45°.

These features should be taken into account in justification of HAC parameters, otherwise, failures are possible in operation of the conveyor. Failures most often affect the conveying belt as it takes up additional load upon violation of force distribution.

The analysis of operation data of the high angle conveyor in Muruntau open pit mine and in foreign deep open pits proves that damages of the conveying belt dominate the other types of failures [13–15]. The causes of the sandwich belt high angle conveyor time-out include: belt damage—33.02%; faults of mechanisms—26.37%; electrics failures—5.39%. The rest down-time is

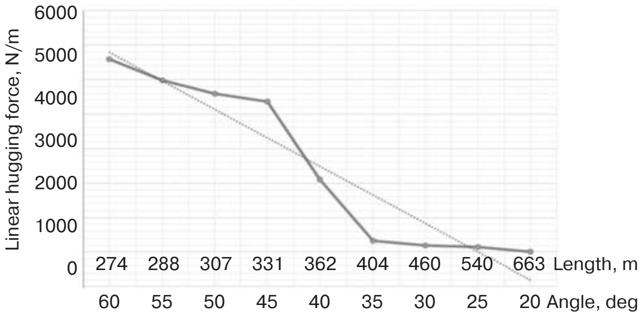


**Fig. 5. Hugging pressure versus HAC length (bottom–top length of high-angle branch) at constant hoist height**

the equipment inspection, the routine and scheduled repair, and random failures.

The causes of the belt damages are different: change in the cargo and belt friction because of the weather or other ambient conditions, insufficient hugging forces, inappropriate contact at the ends of the hugging and conveying belts, etc. As a result, a major force is applied to the cargo-carrying belt and the factor of the belt safety drops, which ends with the belt damage or even rupture.

**Figure 6** illustrates failure events which can cause higher force of pulling and increased load on the conveying belt, namely, deficient contact at the edges of the belts and low hugging pressure—*a*, and insufficient size of the belt unoccupied by the cargo to ensure the wanted contact of the belts at the edges—*b*.

### Conclusions

1. Heavy-duty long high angle conveyors currently in operation in surface mining worldwide have proved their efficiency and can be recommended for application in deep open pit mines.

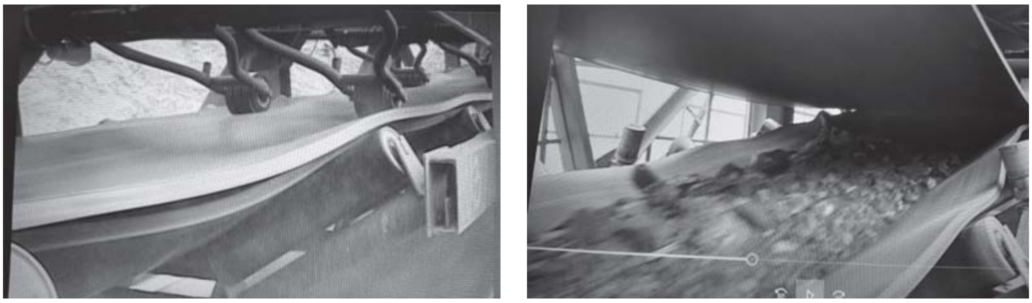

**Fig. 6. Linear branch of sandwich belt high angle conveyor**

2. Design and justification of operating and structural parameters, as well as economic efficiency of sandwich belt high angle conveyors should take into account that:

• the belt of HAC is much wider than the conventional conveyors have in the same operating conditions but the associate increase in cost can be levelled by the decrease in the conveyor length, which furthermore leads to the decrease in the weight of the metalware;

• the design of the sandwich belt high angle conveyor includes the hugging and the conveying belts which have lower total strength than the conventional conveyor has in the same operating conditions;

• the hugging force of the sandwich belt high angle conveyor is a function of both the belt angle and length, and increases with an increase in the latter.

3. The Russian and foreign research shows that the heavy-duty sandwich belt high angle conveyors provide overwhelmingly higher efficiency than the conventional belt conveyors, especially in operation with the cyclical-and-continuous technology in deep open pit mines.

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# ROLLING RESISTANCE COEFFICIENT OF BELT CONVEYOR ROLLERS AS FUNCTION OF OPERATING CONDITIONS IN MINES

*The article describes the theoretical and experimental studies into the rolling resistance coefficient of rollers of belt conveyors in mines. The experimental testing based on the theory of similarity and dimensions has produced the relationships of the rolling resistance coefficient, the main structural parameters of bearings and the service properties of plastic lubricants at dynamically varied temperature and different belt speeds and roller loads. The reduction in the rolling resistance force applied to the rollers at the adjusted rolling resistance coefficient makes it possible to increase the operating energy efficiency of belt conveyors in mines due to the rational use of modern plastic lubricants.*

***Keywords:*** *belt conveyor, belt resistance calculation, belt conveyor roller, bearing assembly, types of plastic lubricants, operating temperature, roller load, belt speed*
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## Introduction

Advancement of mining industry in Russia raises quality standards of mining machinery. No mine is imaginable without transportation, and a specific place in this regard belongs to the conveyor transport [1].

Operating efficiency of a belt conveyor depends on many factors. The conveyor roller is the main component of the conveyor design. The failure-free performance of the conveyor rollers governs the belt service life and the operating