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The use of mine warehouse stocks for the correct completion of mining belt conveyors

The article presents the principles of the rational use of conveyor subassemblies owned in underground coal mining plants for the purpose of listing complete devices appropriate for specific locations and required operating parameters. Since these are often units from different manufacturers, the user will be required to prepare a collective User Manual and issue a Declaration of Conformity.

Key words: *belt conveyor, mining plant, components of belt conveyors*

1. INTRODUCTION

Belt conveyors are currently not subject to the requirement to obtain the approval of the President of the State Mining Authority and are operated on the basis of the EC declaration of conformity and the manufacturer's manual. The manufacturer of the conveyor does not always have to be its actual manufacturer, but can also be only the assembler, assembling the device from ready-made components. Such an assembler can also be a mining plant that has components from dismantled equipment or is able to obtain them within the mining group, for example from liquidated plants. It is very important to receive the source technical and operating documentation or operating manuals together with the acquired assemblies. In the case of drives, there should also be documents for gears, motors, brakes, and clutches. Since the issuance of the EC declaration of conformity is subject to a number of requirements set out in EU and national regulations, the user rarely decides to act as a picker as there is often the fear that the completed device will not meet the safety requirements. In this case, specialists from external companies can always be used to prepare the proper assembly, and the finished device can be voluntarily certified. In the following paper, the issues crucial for the safe operation of the conveyor are discussed, related to the determination of basic operating parameters, such as the selection of drives, brakes, tensioning devices, and the use of guards for hazardous places, as well as the basic principles of assembling subassemblies in the conveyor. This information should be helpful for the representatives of the mining plant both when they complete the conveyor assembly themselves and when preparing tender requirements for engineering companies.

2. PROPER SELECTION OF POWER AND LOCATION OF DRIVES AND OTHER UNITS FOR VARIOUS OPERATING CONDITIONS

Currently installed conveyors should not be configured on the basis of power selection nomograms, in which the conveyor parameters are largely parameterized and contain too many generalized initial assumptions. Knowledge of belt conveyor theory is also required for the use of commercially available power selection software.

In order to correctly estimate the power, it is necessary to know the drag coefficient, resulting mainly from the used route structure, the quality of the rollers and the belt, the number and the construction of drums.

Concentrated resistances should also not be overlooked. It is important to take into account the length of the loop, the increased number of scrapers and the appropriate number, length, and geometric parameters of the transfers. Considerable power is consumed by the sliding support of the belt in the discharge beds.

The rule should be adopted that the conveyors in which the motors work as brakes should have a greater reserve of installed power in relation to the calculated one, so as not to cause the belt to acceleration (loss of motion stability). Conveyors with negative power during steady state operations in a loaded state (braked conveyors) should be configured with drives from the return side. In earlier conveyor designs, which were characterized by significant resistance, the downward slope limit for this type of configuration was –5°. Currently, taking into account energy-saving low-resistance constructions, this limit may be as low as –3°.

The tensioning station, due to the function it performs, i.e. ensuring the correct frictional coupling in the drive and the correct sagging of the belt between the idler sets, should always be on the side of the lower forces in the belt. In descending conveyors, the station should be placed in the discharge area, and in conveyors located in horizontal excavations or working uphill, the station should be located behind the drive in the direction of the belt. In the case of large upward inclination (over 10°), in order to limit the required force in the station, it can be installed in the area of the turning point. With the drive, the tensioning force will be higher by the value of the longitudinal component of the belt gravity force on the section from the drive to the tensioning station, and the tensioning force in the station can be reduced by this value.

A separate issue are conveyors that periodically change the direction of the resultant force vector in the drive, but it is difficult in this case to recommend typical tensioning stations.

In long conveyors with high power requirements, intermediate drives can be used in order to:

- increase the operational capacity or length of the conveyor above its factory data, calculated from the applicability diagrams;
- reduce the maximum belt tension, and thus its required strength;
- facilitate the start-up of conveyors;
- facilitate the braking of conveyors [1].

3. BRAKING – SELECTION OF PARAMETERS, CRITERIA FOR USING BRAKES AND BACKSTOPS

In terms of the construction of conveyors, their conditions of use and applied brakes, conveyors can be divided into three groups:

1) descending conveyors, in which the direction of the braking torque vector is identical to the direction of the driving torque vector;
2) ascending conveyors, where there is a risk of the belt reversing when the loaded conveyor stops;
3) flat and slightly inclined conveyors, in which its own resistance will always stop the conveyor, and the brake is only used to shorten the belt run-out distance after turning off the motors and to protect against uncontrolled belt movement during stopping.

Braking efficiency means ensuring a certain stop for each load condition of the conveyor. The condition for the effective braking process when brakes are installed in the drive unit is, as is known, to ensure frictional coupling between the belt and the drive drums.

Braking safety is a guarantee that there will be no significant slack of the belt at the discharge during braking, loss of spoil from the belt as well as the belt's retraction on the boom and turning point after the braking process is completed or before the next start-up after loosening the braking elements.

When using the program to calculate the conveyor parameters, it should be ensured that braking torque is selected in such a way that the conveyor overrun during braking does not exceed 10 m (note that the braking torque has a negative value). This applies to conveyors operating on slopes from 0° to –14°. Conveyors on inclines from +1° to maximum inclines uphill have a free run (without a brake) which is always less than 10 m when loaded, and empty conveyors require a braking torque of only 9% of the torque of the installed motors to meet this condition.

Overly long braking time due to too weak brake results in:

- the need to use special brake designs, as linings used in traditionally brakes would wear out too quickly;
- the need to extend transfers, sometimes to the capacity of several tons of excavated material, if the receiving conveyor stops faster;

- the risk of the conveyor belt accelerating if the brakes wear out quickly;
- excessive heating of the brakes, creating a potential source of ignition.

Conveyors operating downhill should have a surplus of braking torque also for some rather obvious reasons. If it is necessary to replace the brake lining on a single pair of calipers, then the remaining ones should make it possible to keep the loaded belt still.

When analyzing the data from Table 1, it should be noted that stopping the conveyor too quickly on large slopes may be the reason for undesirable sliding of the excavated material on the belt, while in the case of medium slopes, where a significant braking torque is required to achieve a short run-up of the belt, it is worth considering the division braking moment to more than one place of operation. One of the solutions here may be belt-to-belt intermediate drive units equipped only with a brake, placed in the conveyor route [2].

On ascending conveyors, the braking system should ensure shortening of the empty run-down of the conveyor after turning off the motors and protection against the belt reversing after stopping. In this case, regulation [3] requires that on a slope of more than 5°, the drive must be equipped with an automatic device to immobilize it after stopping. This function is performed by anti-return backstops. On the other hand, the values of the braking torque during the stopping process, which guarantee the correct running of the belt after switching off the drive, are much lower than the driving torque of the motors.

Table 1

Conveyor braking parameters B = 1200 on falls
(N = 500 kW, Q = 1200 t/h, v = 2.5 m/s)

Lean α_0 [°]	L_{max} [m]	P_H/P_N for L_H = 10 m	t_H for $P_H = 1.3\ P_N$ [s]	L_H for $P_H = 1.3\ P_N$ [m]	$t_{H\,min}$ [s]
–14	704	1.326	8.696	10.87	7.363
–13	763	1.345	9.201	11.50	4.832
–12	832	1.368	9.802	12.25	3.596
–11	915	1.395	10.525	13.16	2.865
–10	1018	1.428	11.416	14.27	2.381
–9	1148	1.470	12.540	15.68	2.038
–8	1316	1.525	13.992	17.49	1.781
–7	1540	1.598	15.944	19.93	1.582
–6	1864	1.702	18.712	23.39	1.424
–5	2355	1.861	22.961	28.70	1.295
–4	3190	2.133	30.201	37.75	1.188

Designations:

L_{max} – the maximum length of the conveyor determined according to DIN 22101 for the output data as in the title of the table;
P_N – braking force of steady motion (from drive motors);
P_H – braking force caused by braking devices when stopping the conveyor;
t_H, L_H – braking time and distance;
t_{Hmin} – the minimum braking time at which the excavated material does not slide down the belt for the material–belt friction coefficient μ = 0.285 (95% of the rubber–carbon coefficient of friction μ_{gr} = 0.3), determined according to the formula $t_{H\min} = v/\left[g \cdot (\mu \cdot \cos\alpha - \sin\alpha)\right]$.

According to the data in Table 2, a backstop with a nominal torque of at least 75% of the drive torque in combination with a brake providing a torque during stopping the conveyor (especially when not loaded) with a value of approximately 10% of the drive torque is a sufficient guarantee of safety in the case of extreme slopes.

In practice, the installed brakes have a torque comparable to the driving torque, which in effect doubles the protection of the return movement and significantly reduces the coasting when stopping. However, it is possible to safely perform work on the backstop without the need to empty the conveyor of the transported material.

However, it is not advisable to resign from the installation of the anti-reverse brake, i.e. the so called backstop in favor of the brake itself, because its absence may cause the belt to retract during the start of the conveyor (when the brake is released and the motor does not yet have full drive torque) [4]. In order to obtain smooth stopping, it is enough to delay in the operation of the brakes, i.e. to engage the brake in the final phase of the conveyor's stopping or to install a brake with a variable braking torque, which works with a minimum torque during stopping, and achieves a full braking torque just before stopping.

Table 2

Conveyor braking parameters $B = 1200$ on inclines
($N = 500$ kW, $Q = 1200$ t/h, $v = 2.5$ m/s)

Lean α_0 [°]	L_{max} [m]	s [m]	s_0 [m]	P_{H0}/P_N for $L_{H0} = 10$ m	P_{BS}/P_N
0	2955	12.07	11.70	0.073	–
1	2100	8.92	12.43	0.077	–
2	1640	7.20	13.20	0.080	0.14
3	1342	6.09	13.94	0.082	0.29
4	1136	5.33	14.63	0.083	0.39
5	986	4.78	15.34	0.085	0.46
6	870	4.35	15.98	0.085	0.52
7	778	4.01	16.54	0.085	0.56
8	704	3.73	17.13	0.086	0.60
9	643	3.51	17.67	0.086	0.63
10	592	3.32	18.23	0.086	0.65
11	550	3.16	18.83	0.087	0.67
12	512	3.02	19.29	0.087	0.69
13	480	2.90	19.90	0.088	0.71
14	452	2.80	20.42	0.088	0.72
15	427	2.70	20.97	0.088	0.74
16	404	2.62	21.55	0.089	0.75

Designations:
- s – free coasting (without brake) of the full conveyor;
- s_0 – free run of an empty conveyor;
- P_{H0} – braking force ensuring a 10-meter run-out of an empty conveyor;
- P_{BS} – the force preventing the belt from reversing, determined as the difference between the vertical component of the gravity of the transported material and half of the conveyor's resistance $P_{BS} = 1.5 \cdot m_u \cdot g \cdot \sin\alpha - 0.5 \cdot P_N$. Only positive values are included in the table.

In uphill working conveyors, there is no need to install special constructions of braking devices with programmable operating characteristics, the value of which sometimes exceeds the cost of other drive components. Such special systems may sometimes be advisable on downhill conveyors where it is particularly important that the brake engages immediately to prevent the belt from accelerating before the braking process begins.

There is another group of users who promote the idea that it is possible to resign from installing brakes in conveyors operating horizontally and at an inclination of up to +5°, based on the above-mentioned provision on the use of automatic devices on inclinations above 5°. This may be possible for some conveyors used in preparatory work in horizontal galleries, but in general conveyors without brakes may have too long run-out of the belt after the drive is turned off and uncontrolled movement of the belt at chutes, turning points and places where the conveyor route runs on a variable incline. However, in the case of transporting people, the requirement to install a brake is absolute, regardless of the inclination, due to the need to effectively stop the conveyor [5].

The most difficult, both in terms of the selection of components and in operation, are conveyors installed in galleries with an inclination between –2° and –3°. Within this range of inclinations, there is a boundary between driven and braked conveyors during steady-state operation. There may be cases of power consumption from $-N_N$ to N_N depending on the degree of filling of the conveyor. In special cases, the power consumption may be zero. Therefore, in this range of inclinations, brakes should be selected as for descending conveyors, while the conveyor structure should be additionally equipped with a tensioning device, compensating for unfavorable phenomena in the belt during braking (e.g. running up of the belt to the discharge).

4. BELT TENSIONING-TENSIONING SYSTEMS AND SELECTION OF THE RIGHT TYPE OF TENSIONING DEVICE

Problems related to incorrect belt tension occur mainly in conveyors operating underground in mining plants. This is mainly due to the fact that conveyors operating on the surface are most often equipped with gravity tensioning stations, which are simple both in terms of construction and calculation. Their proper selection does not pose any problems, as they are easy to describe mathematically and, therefore, tables can be prepared for selecting the weight of the tensioning device. Also, the wrong selection of the device can easily be corrected by changing the number and weight of the loads.

High power surface conveyors are usually equipped with winch tensioning devices. The problem of frictional engagement is solved by means of a sufficiently high initial tension, a high-strength belt (usually with steel cords) and start-up mitigation systems.

The simplest tensioning device with continuous operation is a gravity station, however, in the domestic coal mining industry, in underground conveyors, due to the limited dimensions of excavations, towers with weights are not installed. On the other hand, for the reasons discussed in Chapter 3, heavy brakes are often required on conveyors, and the gravity station can generate significant dynamic forces when braking from the rapid throwing of the tensioning load.

Incorrectly selected tensioning and starting systems causes the following phenomena, which increase operating costs and introduce various types of hazards during conveyor operation:

- slip on the drive drums reducing the durability of linings and bearings,
- variable loads in the range from full loosening to sharp jerking above the permissible loads affecting the life of the belt and its connections,
- knocking out or seizing of bearings in idlers and non-driven and tensioning drums,
- damage to structural elements, in particular fixing and anchoring elements.

The ideal tensioning system should have:

- ensuring proper belt tension for all dynamic states of the conveyor,
- responding to load changes,
- immediate reaction (possibly without “dead zones” of insensitivity),
- automatic operation also after disconnecting the voltage,
- causing the belt tension to be as low as possible.

Unfortunately, winch systems, even those equipped with high-end electronics, give results which are far from expectations. The main problem is the inertia of the winch drives and the considerable power necessary to achieve the follow-up of changes in the tensioning force in relation to the changes in the drive torque. An additional unfavorable phenomenon occurs when the conveyor is switched off under load. Figure 1 shows the course of the force S_2 after the emergency shutdown. The parking force in this case is much higher than the one set on the sensors. As a result, during the next start-up, the belt is slackened instead of tightened. A winch station without automation shows a course of forces such as the forces marked as S_1, S_2 in Figure 1, i.e. for the correct operation of the conveyor, the initial tension must be applied much higher than required due to the installed power. Such a tensioning system can be used for medium-power conveyors with lengths not exceeding 800 m. For high-power conveyors and longer lengths, continuous tensioning devices should be used to avoid problems during start-up and braking.

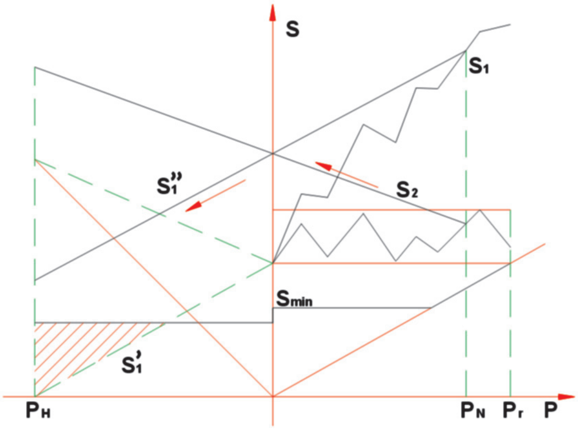

Fig. 1. Winch tensioning – diagram of forces in the drive S_1 and S_2 as a function of circumferential force P

Designations for Figure 1:

- P_N – circumferential force on drive drums for nominal load,
- P_r – circumferential force during start-up,
- P_H – circumferential force required for braking,
- S_1 – force in the belt running over the drive drums,
- S_2 – force in the belt running from the drive,
- S_{min} – the minimum force in the belt determined from the condition of allowable sag of the belt between idler sets.

Hydraulic tensioning has more favorable characteristics than winch tensioning, and the main objection to this type of tensioning is the possibility of excessive sagging of the belt on the side running towards drive during braking. However, this problem can be solved by using a second tensioning system that eliminates this phenomenon [6]. Hydraulic tensioning requires considerable amounts of working medium to ensure continuous operation at start-up in high-power conveyors, which, however, is partly compensated by the use of hydroaccumulators in the system.

Tracking mechanical tensioning (with a rope system), used in the longest and most difficult hauls, is very close to the optimal characteristics of changes in the tensioning force. A certain limitation of the use of follow-up stations is the need to set higher preloads at inclined conveyors.

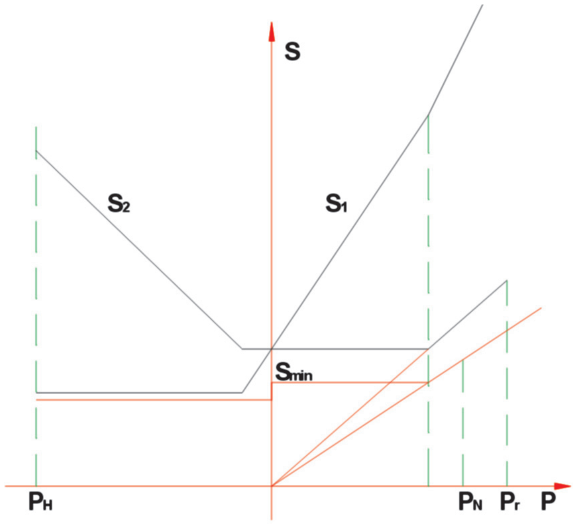

Fig. 2. Follow-up tensioning with constant force module

Figure 2 shows the operation characteristics of the coupled station, which allows the optimal values to be approached [7]. In the insensitivity area of the follow--up station, a constant tension hydraulic unit operates here. The low operating costs of conveyors equipped with new generations of tensioning devices (mainly savings due to the increase in the life of the belt and its connections and drive components) prove that conveyors operating in high-performance hauls should be increasingly equipped with this type of tensioning system.

5. THE USE OF COVERS FOR MOVING ELEMENTS, PLACES OF INSTALLATION AND METHOD OF ASSEMBLY

The scope of application of covers on a belt conveyor is defined by several sources, both standards and health and safety regulations. However, there are no unambiguous regulations regarding mining underground coal conveyors. Records [8] can be used, and dangerous places in conveyors are defined by the standard [9]. However, the basic premise, apart from these specific provisions, should be the principle that, for safety reasons, the operator should not be prevented from cleaning the assemblies or adjusting the belt run. Therefore, the places where scrapers are installed should not be excessively fenced off or devices for removing slurry should be installed.

Adjustment elements should be located in such a way that access to them does not require disassembly of covers. A special place is the loop trolley, but also here you can reduce the risk resulting from the disassembly of the covers, e.g. by using barreled drums, which are much better for guiding the belt, as well as additional guide rollers.

To facilitate the operation of the conveyor, it can be equipped with central lubrication systems. They do not have to be automatic extensive installations, but piping systems led from the grease nipples to one place within the assembly where the grease gun can be safely used.

Communication passages should be separated for the staff and other people moving nearby. Where the dimensions of the excavation do not allow for the construction of passages over the belt, it is often possible to safely fence off the passage between the belts or even under the conveyor.

The danger zone for people staying near the conveyor is the transfer areas. Guards that prevent access to the places between the side restraints and the belt are very important here, as shown in Figure 3. Guards should also protect against impact by falling material.

Fig. 3. Example of the arrangement of the guards of dangerous places (positions shown in red)

6. BASIC PRINCIPLES OF SELECTION OF UNITS IN THE CONVEYOR

Multiple mergers of mining plants and the transfer of unprofitable branches to a mine restructuring company mean that conveyors from different manufacturers may appear in one mining plant, which ensures the correct selection and operation of the equipment under specific tenders. After the warranty expires, these devices are at their user's disposal, but it is not always possible to find a new location where the device can be used under the existing conditions of use. Often, a drive with the power required in a given location is supplemented with other units from conveyors normally used in a given area. Therefore, the assembly of the conveyor from the subassemblies owned by the mine should be preceded by calculations using the software available on the market, not only selecting the required power, but also braking parameters, tensioning forces and the length of the tensioning device run-out. Currently, most mines have such software.

Subassemblies for the conveyor should be adapted to the forces occurring in the conveyor system, so their usefulness should be assessed on the basis of the source technical and operating documentation of the conveyor from which the given unit comes. It is especially important to check the size of the bearings in the drive and return drums as well as the diameters of the drums for the belt expected in the conveyor. The load capacity of the bearings should ensure their durability of 20,000 hours, or 50,000 hours at specific loads.

The route of the conveyor should guarantee the assumed capacity, therefore the size of the trough should also be checked during the preliminary calculations. Significantly corroded and deformed route elements should not be used.

The diameters of the idlers used in the conveyor should be selected so that their rotational speed does not exceed 600 rpm at the assumed belt speed. For higher rotational speeds, it is necessary to use special roller supports with rollers secured against falling out.

There is no need to connect together units that do not come from the same type of conveyor, if we provide them with individual and reliable fixation while maintaining the axis of the conveyor. This applies in particular to the connection drive–loop or route–turning station. First of all, it is necessary to check the passage of the belt between the units and in the event of a required height adjustment or a section requiring additional belt support, equip it with additional deflection drums.

If the boom is placed on a stand, when it is not fastened to the drive, the running belt must be additionally shielded in front of the drive.

A separate problem is the selection of the belt and the use of the used belt, but here the rule should be adopted that for important belt haulage it is recommended to buy a new belt and use it later for less responsible departmental haulage and in conveyors for preparatory work.

7. SUMMARY

1) The issuance of the EC declaration of conformity must be preceded by a risk analysis and assessment [10], confirming the fulfillment of the essential requirements of the machinery directive and the ATEX directive and other, if applicable, based on harmonized standards.
2) The supplier of the device is responsible for the safety of the structure. If the declaration is issued by the picker, he is responsible for the correctness of the device. Therefore, it is recommended that the so-called "own sets" subject to voluntary certification.
3) Modern mining belt conveyors should always be configured for specific tasks and locations, with particular emphasis on ensuring work safety in transient states.
4) Conveyors in which units have been put together by the use are sometimes operated on the basis of the manufacturer's initial documents, despite the fact that the scope of the interference in the construction is so large that it requires issuing a new declaration of conformity, therefore should always be carefully analyzed the conditions of use specified in the device's instruction manual in terms of compliance with them. The use of units from several manufacturers in one conveyor is a significant interference.
5) The use of units owned by mines allows one to reduce the costs of preparing new transport routes, as incomplete devices from decommissioned parts of mining plants can be used as fully-fledged devices after verification, analysis and completion, subject to the above comments.

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