Resistances to the motion in mining belt conveyors

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Research workers of the Silesian Technical University (Antoniak, Lutyński, 1999) have been carrying out measurements on mining belt conveyors for years. The tests covered belt conveyors characterized by considerable lengths and high capacities, complicated configurations of a conveyor route and equipped with driving systems of different type in which soft starting facilities were incorporated or not included. One of the objectives of the tests was to determine quantities of principal resistances to motion the results of which have been presented in this paper.

Key words: mining, principal resistances to motion, belt conveyor, field measurements.

Decrease - oriented tendency in resistances to the motion in belt conveyors

The results of a great number of field measurements taken on belt conveyors allow to conclude that a high accuracy of calculations of principal resistances to the motion is obtained when using a basic method as described in the standard DIN 22101 on condition that the coefficient f of principal resistances to the motion has been properly selected.

Among principal resistances to the motion are included: resistances to idler rotation, indentation rolling resistances, flexure resistance of the belt and flexure resistances of bulk material. The coefficient of principal resistances to the motion f combines the force of gravity of a sum of masses being in motion with principal resistances to the conveyor motion F_P, N thus

$$F_P = f \cdot g \cdot \Sigma m \quad \text{N}$$

where Σm – sum of moving masses, kg,
           g – acceleration corresponding to the force of gravity, m/s^2.

It is considered that a standard quantity is $f = 0.02$ but in the case of underground mining $f = 0.025$ or $f = 0.03$. Among lumped resistances of a conveyor F_L, N are included: resistances to belt bending on drums, rotation resistances of all drums, resistances when loading the material to be conveyed, and resistances of belt cleaners. Lumped resistances are expressed as a coefficient of length C:

$$C = \left(F_P + F_L\right) / F_P = 1 + F_L / F_P$$

Combining C and f together brings about

$$F_P + F_L = C \cdot f \cdot g \cdot \Sigma m \quad \text{N}$$

When taking into consideration additional resistances produced e.g. by advancing arrangement of idlers in relation to the direction of the belt movement F_A, N and resistances of lifting and lowering of the material being conveyed F_{LL}, N a total resistance to the motion is obtained which allows to determine the drive's power.

A distribution of the power consumption given in percentage of power used to overcome particular resistances to the motion in long belt conveyors laid horizontally (of about 1.5 km in length) is presented in fig. 1.

Recently a lot of attention is given to the problem of decreasing the power consumption in drives of a belt conveyor. This purpose was achieved by the application of drives controlled with frequency converters, introduction of special idler sets resulting in the reduction of resistances to the belt bending and of rolling resistances as well as in consequence of the use of special cover plies made from synthetic plastics characterized by decreased rolling resistances. The experience of the Goodyear Company gained in the course of selecting the
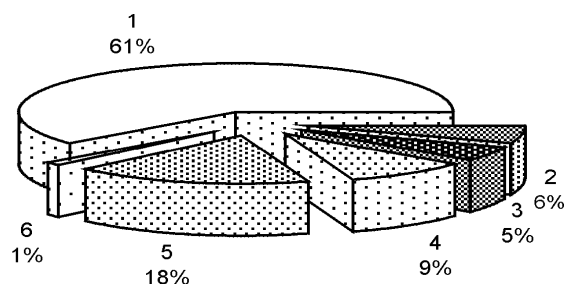

Fig.1. Conveyor power consumption for long horizontal profiles 1 – indentation rolling resistance, 2 – flexure resistance of bulk material, 3 - flexure resistance of the belt, 4 – bearing resistance of the idler, 5 – secondary resistances, 6 – extraordinary resistances

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materials for tyres finds an application here. The reduction of power consumption in conveyor drives as shown in fig. 2 is a result. In order to reduce the power requirement for drives of long underground belt conveyors, the number of tilting idlers in the top strand is limited. The tilting is usually of 1.5 to 2.5° and its role is to align the belt run. From field measurements of such conveyors (Sołtysik, 1999) it appears that reduction of the number of idlers covering an advance in the top strand by 63, 62% has brought about a decrease in the power requirement shown in fig. 3.
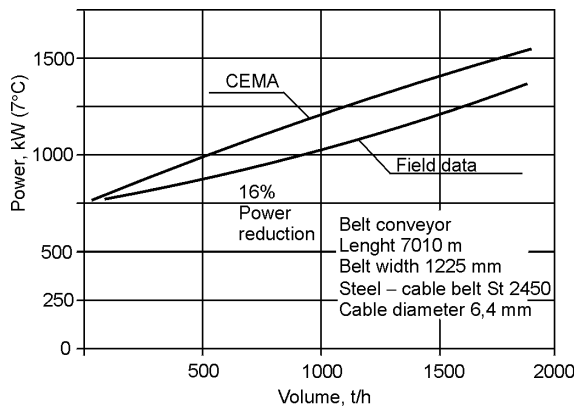

Fig.2. Power consumption by the belt conveyor with the belt made from materials of low-rolling resistance (Belt Conveyors for Bulk Materials).
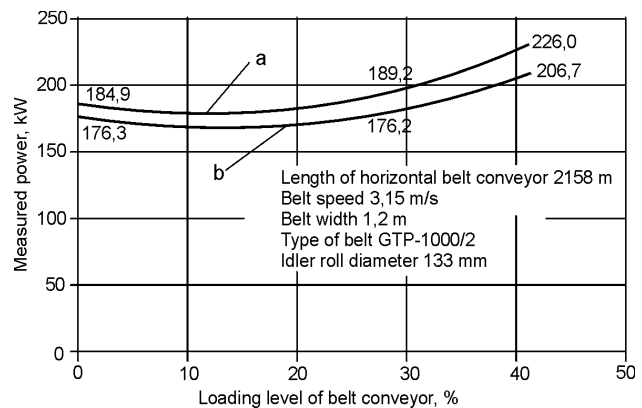
Fig.3. Conveyor power consumption for long horizontal profiles equipped with 100% tilting troughing idlers (curve a) and with 36,4% of tilting troughing idlers in the upper strand (curve b).

The detailed calculations have indicated that in case of an empty conveyor the resistance to the motion produced by the advancing arrangement of side idlers (being here of 2.5°) in the top strand can be calculated with a high accuracy using the formulae by prof. Vierling (Antoniak, 1992). The resistance measured on one set amounted to about 2.12 N and the calculated was of 2.23 N. Whereas in case of a conveyor loaded to about 40% of the nominal load capacity the measured resistance to motion was about 5.63 N and the calculated resistance amounted to 6.67 N and so the increase in the resistance calculated related to the measured amounted to 17%.

Field tests of a belt conveyor

The objective of the performed measurements and tests on the belt conveyor type Gwarek 1000 made by the Pioma Mining Machinery Factory and characterized by complicated configuration of the conveyor route (and by standard operating parameters which has been in operation in one of coal mines) was to recognize and determine its static and dynamic properties. The tests carried out made it possible to assess the operation of this belt conveyor and to draw general conclusions as regards belt conveyors operating in other coal mines and installed in roadways inclined at different gradients.

Only results of an analysis of resistances to motion in a belt conveyor have been presented in this paper. A long belt conveyor type Gwarek 1000 characterized by a complicated configuration of its route, installed in the inclined drift I and in the cross-cut parallel to 900 m. level was subjected to tests.

On the basis of the tests and listing, the detailed geometry and operational parameters of the belt conveyor have been determined. A horizontal length of the conveyor amounted to 939.4 m. and its length measured to the dip of 353.3 m. The inclination was of 14°. The radius of convex curvature was of 85 m with the central angle being 15°.

The belt conveyor of the type Gwarek 1000 under testing incorporates the following major units: an intermediate double drum transfer drive of the NPz-1000 type, a one-layer loop take up along with a belt tensioning facility of the ZNH-1200 type with an electrically driven winch unit for belt storing, a discharging station, a belt deflecting facility, a turning station, a charging facility, a conveyor structure with three top roller idler sets and two bottom roller idler sets as well as the conveyor belt of 1000 mm in width made by FTT Stomil Wolbrom, Joint Stock Company.

The drive is an intermediate double drum transfer drive. The belt wrap through driving drums is 210°. The drive is equipped with disk brakes type ZRHT-5 supplied with emulsion and the braking moment of each brakes 3400 N·m. Each driving drum is driven from one two-speed electric motor type SGS 315M-12/4 of 45/132 kW in power and 1000 V of applied voltage. Electric motors are connected to toothed gears via flexible couplings type SP-100, as made by the Pioma Mining Machinery Factory and designed for transmitting the maximum circumferential force of 100 kN. The toothed gears incorporated in the drive are cylindrical, intersecting axis gears.

Technical data of the conveyor useful for calculating of the principal resistance's to the motion are presented in table 1.

Specification	Unit	Value	
Conveyor length L_c	m	1292.7	
Belt length L_{ct}	m	2626.6	
Belt pretension	N	11000	
Unit mass of belt type GTP 1250/3, q_t	kg/m	24,5 (partly worn)	
Mass of rotating parts of one normal idler roller: top idler bottom idler	kg	φ 108x380 - 4.6 φ 108x530 - 6.5	
Mass of rotating parts of one reinforced idler roller: top idler bottom idler	kg	φ 108x380 - 6.88 φ 108x530 - 8.42	
Total mass of rotating parts of idler rollers: top idler m_{kg} bottom idler m_{kd}	kg	261x4.6+2322x6.88 =1 7176 692x6.5+38x8.42 = 4818	
Belt speed when running: in first gear v_I in second gear V_{II}	m/s	1.082 -	- 3.246
Power of motors M1 and M2 taken from oscillograms: 0101 0102	kW	- - M1 = 29.65 M2 = 26.1	M1 = 74.5 M2 = 69.4 - -
Coefficient of length C (loop take-up + 8 drums) acc. to DIN 22101	-	1.0765	
Conveyor length on a level L_p	m	921.57	
Conveyor length on slope (arc length in vertical plane is included in the conveyor length on slope) L_n	m	371.13	
Angle of longitudinal inclination of the conveyor α	degrees	14	
Angle of advance of rollers in idler sets: top idler sets ε_g bottom idler sets ε_d	degrees	2 1°20'	
Angle of inclination of idler rollers: top idler rollers β_g bottom idler rollers β_d	degrees	in 861 sets 35 in 365 sets 13	
Troughing coefficient c_g	-	0.35	
Coefficient of friction of the belt against idler roller μ	-	0.4	
Spacing of idler sets: top idler sets bottom idler sets	m	from 1 to 1.7 3 and 6	
Additional coefficient for empty belt, c_d	-	1,3	

Measuring system used for testing of the belt conveyor

When carrying out the tests of the belt conveyor, the apparatus incorporated in the measuring system the diagram of which is shown (in fig. 4) have been used. The whole measuring system is composed of two parts:

− a measuring system installed underground and designed to measure and to store any analog signals,

− a system for processing the data coming from measurements under laboratory conditions on the surface.

Reading of the memory of the MS2 data logger takes place on the surface or (in exceptional cases) underground. It is effected through series connecting the logger to a junction of a computer type PC via interface. The measurements read out are properly formatted so that they are applicable for further detailed handling and for statistical analysis with the aid of analysing program.

The measuring apparatus, along with units controlling the operation of the conveyor under testing, constituted the measuring positions. A variety of the measurements was carried out to determine the location of these measuring positions.
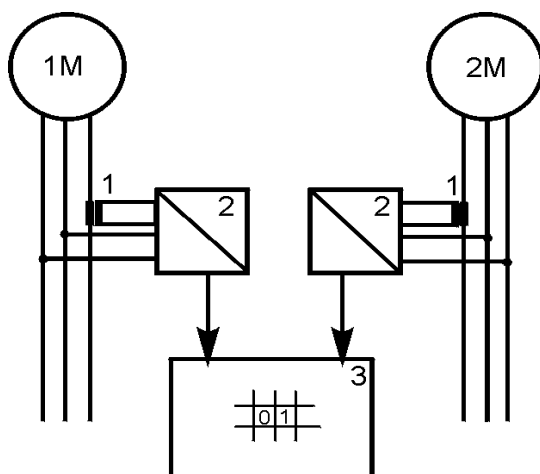
Fig.4 Block scheme of measurement system 1 – current transformer, 2 – analogue converter of electrical quantity of SML type (produced by Reader), 3 – digital recorder of MS2 type (produced by DMT Germany)

Depending on a measurement taken, proper sensors were arranged and built-in the conveyor. Signals sent by sensors were recorded. A diagram of the measuring system and the arrangement of sensing elements picking up the force, pressure, peripheral speed of the driving drum, belt speed and that of converters of electrical quantities (power, voltage and current) in the conveyor under testing have been presented in fig. 5.
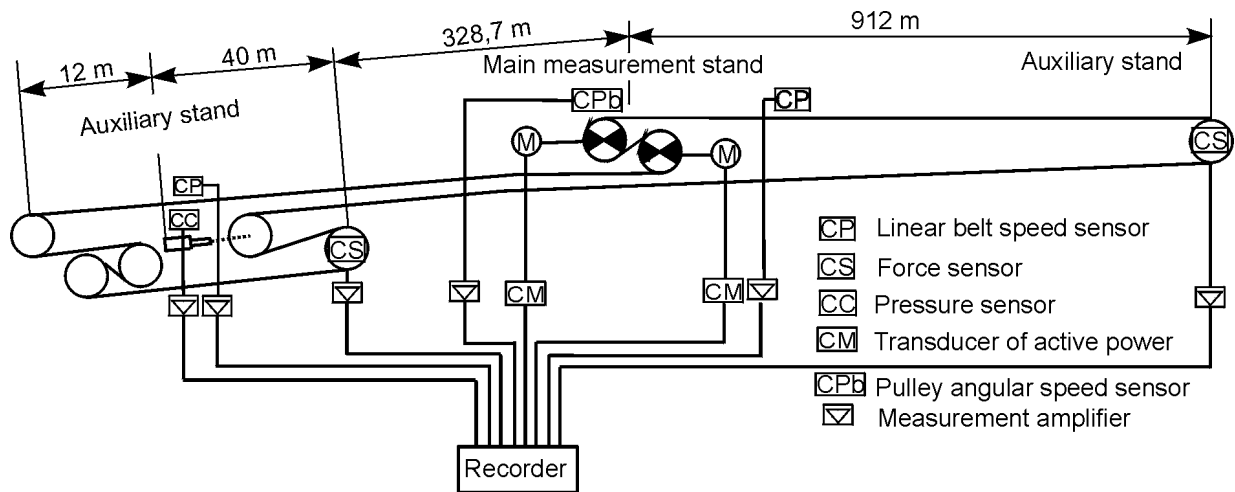

Fig.5. Location of measuring sensors and scheme of measurement system

Calculation of the value of the coefficient of principal resistances to motion in the tested belt conveyor

Using the data from table 1 and from the oscillogram no 0101 (fig. 6) for the nominal speed of belt v_{II} = 3.2467 m/s and for the operating tension of the belt 11000 N, as well as the data from the oscillogram 0102 for the reduced speed of belt v_I = 1.082 m/s and operating tension of the belt of 11000 N and employing the analytical relationships developed for the principal resistances to motion in a belt conveyor (see DIN 22101) designated with the letter *f,* values of the resistances have been calculated. The tables 2 and 3 contain the results of the calculations carried out.

Additional resistances produced by the advancing arrangement of top and bottom idlers have been calculated using the results of measurements (Sołtysik, 1999) and the formulae developed by prof. Vierling (Antoniak, 1992). From the arguments of prof. Vierling it appears that the resistance of an advance for one idler set is determined by the relationship:

for top three roller idler set

$$F_{zwg} = I_{zg} \cdot c \cdot c_d \cdot \mu \cdot g \cdot \left(q_t + q_u\right) \cdot \cos\alpha \cdot \sin\varepsilon_g \quad \text{N}$$

and for bottom two roller idler set

$$F_{zwd} = I_{zd} \cdot c_d \cdot \mu \cdot g \cdot q_t \cdot \cos\alpha \cdot \cos\beta_d \cdot \sin\varepsilon_d \quad \text{N}$$

where
c – trough coefficient (assumed as $c = 0.35$),
μ – coefficient of friction of a belt against the idler (assumed as $\mu = 0.4$),
c_d – additional coefficient in which the resistance resulting from a contamination of rolleridlers and resistance produced by a high number of roller idlers' revolutions (~ 557 1/min) and by their small diameter have been taken into account (assumed as $c_d = 1.3$),
ε_g, ε_d, α, β_d – angle of advance in top and bottom idler sets, angle of longitudinal inclination of a conveyor and bottom troughing angle,
I_{zg}, I_{zd} – spacing of top and bottom idler sets, m,
q_t, q_u – specific mass of belt and run-of-mine, kg/m,
g – acceleration of gravity 9.81 m/s^2.

1. Force on the axle of return pulley kN
2. Force on the axle of takeups pulley *100 kN
3. Pressure of belt takeups servomotor *10 MPa
4. Belt speed on the discharging point *10 m/s
5. Belt speed on the drive *10 m/s
6. Linear speed of drive pulley *10 m/s
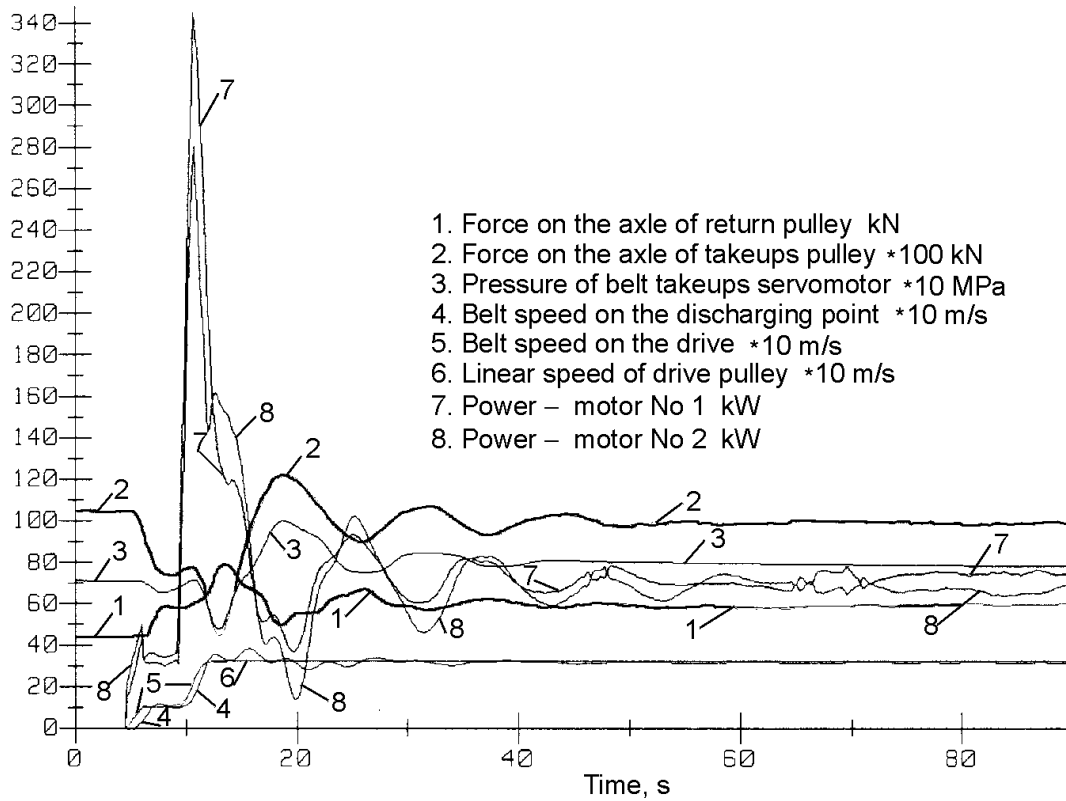7. Power – motor No 1 kW
8. Power – motor No 2 kW

Fig.6. Oscillogram No 0101 presenting the belt conveyor start – up with two speed motor during nominal belt tension.

In the conveyor under testing, all side rollers were assembled in tilted position, it is possible to take the resistance of one idler set as a point of issue and to apply it to all idler sets. This was used when making calculations. The calculated resistances produced by tilted roller idlers have been listed in table 2.

Tab.2. Calculated additional resistances produced by advancing positioning of rollers in top and bottom idler sets.

Specification	Value
Additional resistances in a bottom strand, horizontal F_{wdp}, N	2600
Additional resistances in a bottom strand, inclined F_{wdn}, N	1016
Additional resistances in a top strand, horizontal F_{wgp}, N	1411
Additional resistances in a top strand, inclined F_{wgn}, N	562
Total additional resistances F_w, N	5600
Power corresponding to additional resistances N_w, kW	19.13

The calculations of the coefficient f of principal resistances to motion for two different belt speeds from the measured power of driving motors have been presented in table 3. Oscillograms no 0101 and no 0102 were used for this purpose.

An increased value of the coefficient of principal resistances to motion at a belt speed of 3.246 m/s in relation to values of these resistances stated at lower speed of the belt amounting to 1.082 m/s corresponds with general trends noted in the world literature dealing with this problem. In case of this conveyor designers of the Pioma Mining Machinery Factory at Piotrków Trybunalski have purposely increased the value of the coefficient f of the principal resistances to motion in order to avoid the generator operation of motors when the conveyor is fully loaded with run-of-mine material as well as to prevent problems arising at braking the conveyor and especially those involved in the ejection of the belt on a discharging drive occurring when the conveyor is stopped.

The main resistance to the motion in the top strand have been increased due to application of:

- idler rollers of small diameter 108 mm,
- trough angle of 35°,
- higher belt speed,
- belt with three-interlayer of width 1000 mm,
- all side rollers tilted.

Similarly the increase of main resistance in the bottom strand has been obtained due to application of:
- trough angle of 13º for two rollers,
- greater spacing of roller idler sets,
- all rollers tilted,
- high belt tension during passing over the convex arc,
- suspending of the conveyor structure on the ropes.

Tab.3. Determinination of the coefficient f of principal resistances to motion in the Gwarek 1000 conveyor from active power consumption.

Calculation of the coefficient f from the measured power of driving motors for running speed

$$f_{vII} = \frac{(N1 + N2)_{vII} \cdot 1000 \cdot \eta_m \cdot \eta_{el} - F_w \cdot v_{II}}{C \cdot g \cdot [m_{kg} + m_{kd} + L_p \cdot 2 \cdot q_t + L_n \cdot 2q_t \cdot \cos\alpha] \cdot v_{II}}$$

and for decreased speed

$$f_{vI} = \frac{(N1 + N2)_{vI} \cdot 1000 \cdot \eta_m \cdot \eta_{el} - F_w \cdot v_I}{C \cdot g \cdot [m_{kg} + m_{kd} + L_p \cdot 2 \cdot q_t + L_n \cdot 2q_t \cdot \cos\alpha] \cdot v_I}$$

Assuming $\cos\alpha = 1$ for $\alpha \leq 18^o$ the above equations reduce because

$$L_p + L_n = L_c = 1292.7m$$

in the loop take-up there are 41.2 m. of belt in addition

thus

$$f_{vII} = \frac{(74.5 + 69.4) \cdot 1000 \cdot 0.95 \cdot 0.85 - 5600 \cdot 3.246}{1.0765 \cdot 9.81 \cdot [17176 + 4818 + 24.5 \cdot 2626.6] \cdot 3.246} = 0.0331$$

$$f_{vI} = \frac{(29.65 + 26.1) \cdot 1000 \cdot 0.95 \cdot 0.53 - 5600 \cdot 1.082}{1.0765 \cdot 9.81 \cdot [17176 + 4818 + 24.5 \cdot 2626.6] \cdot 1.082} = 0.0223$$

and finally

$$f_{vI} = 0.0223 \quad \text{and} \quad f_{vII} = 0.0331$$

A pretension of the belt has been selected on the basis of operational experience so that the belt could operate under optimum conditions. The pretension is low and amounts to ca 11000 N. It provides for a correct belt sag over the whole length of the conveyor.

An increase in the belt speed has at the same time brought about an increase in revolutions of idler rollers to 574 1/min and thus above the upper limit (550 1/min) that is permissible in respect to the service life of bearings of the roller idlers.

In order to enhance the service life of roller idlers a top strand of the conveyor has been equipped with rollers of reinforced design with double labyrinth seal and with cast-iron housing of bearings of type 6305. Such idler rollers found also application in a bottom strand of the conveyor in the area of convex arc where a high belt tensioning force appeared.

A value of the coefficient of principal resistances to motion in the belt conveyor type Gwarek 1000 has been calculated from the recorded duration of the empty overrun of a belt, $t_w = 9s$. These resistances are determined by the relationship:

$$C \cdot f_{wwvII} = m_{zr \, przen} \cdot v_{II} / t_w \cdot g \cdot (m_t + m_k).$$

With reduced mass of the conveyor determined ($m_{zr \, przen} = 113730$ kg) it is possible to reckon the product $Cf_{wwvII} = 0.0374$.

Assuming the value of the length coefficient $C = 1.0765$ (DIN 22101) the value f_{wwvII} calculated from the duration of empty run is $f_{wwvII} = 0.0374 / 1.0765 = 0.0347$.

From the above it is evident that the coefficient of principal resistances to motion calculated from the duration of an empty overrun for the running speed v_{II} is by several per cent higher than that calculated from the active power consumption. This conformability is satisfactory in technical aspect.

When analysing the results obtained during the measurements and contained in the oscillograms, it is possible to make an attempt at calculating the value of the coefficient f_{dvII} of principal resistances to motion for a bottom strand of the belt conveyor type Gwarek 1000. The measured quantity of belt tension in the area of the belt tensioning facility S_n N and on a turning drum S_{bz} N constituted the basis for calculations. On the inclined segment of the conveyor, a component of the force of gravity increases the belt tension by the value:

$$S_{dnt} = g \cdot q_t \cdot H = 9.81 \cdot 24.5 \cdot 90.8 = 21830 \text{ N}$$

For the purpose of further calculations it has been assumed that $cos\,\alpha = 1$, thus, after taking into account additional resistances produced by advancing positioning of idler rollers in the bottom strand amounting to: F_{wdp} = 2600 N and F_{wdn} = 1016 N, in total 3616 N, a formula of principal resistances to motion in a bottom strand has the form:

$$S_{bz} - S_n - S_{dnt} - \left(F_{wdp} + F_{wdn}\right) = f_{dvII} \cdot g \cdot \left[L_c \cdot q_t + m_{kd}\right] \text{ N}$$

The value of S_{bz} as taken from the oscillogram no 0120 is 50000 N. From the same oscillogram it is evident that S_n = 10500 N. Substituting the values obtained in the formula we obtain:

$$f_{dvII} = 0.0382$$

The coefficient of principal resistances to motion in a bottom strand of the conveyor f_{dvII} is slightly higher than the coefficient f_{vII} determined for the whole belt conveyor. It has been stated for the first time that f_{dvII} is different from f_{vII}.

Such a high value of the coefficient f_{dvII} of principal resistances to motion in a bottom strand of the belt has arisen from a reduced diameter of idler rollers, increased belt speed, greater spacing of bottom roller idler sets, increased inclination of bottom idler rollers in relation to the level and their advancing positioning over the whole conveyor length as well as from resistances to motion on a convex arc.

With the aim of verifying the correctness of the results obtained, the values of the coefficient of resistances to motion in a bottom strand of the belt have been calculated using another method in which the measured difference in the belt tension on a turning pulley was used. The belt tension recorded at a standstill of the conveyor has been deducted from the belt tension recorded at steady running of the conveyor. For normal pretension of the belt and its speed v_{II} = 3.246 m/s, the following is obtained from the oscillogram no 0103:

$$\Delta S_{bz} = S_{bzrust} - S_{bzsp} = 62000 - 45000 = 17000 \text{ N}$$

thus

$$f_{dvII} = \frac{\Delta S_{bz} - \left(F_{wdp} + F_{wdn}\right)}{g \cdot \left[L_c \cdot q_t + m_{kd}\right]} = \frac{17000 - 3616}{367840} = 0.0364$$

The value of this coefficient received in the course of analogous calculations though carried out at the increased pressure in a cylinder of belt tensioning facility (higher pretension of the belt) and at the belt speed v_{II} = 3.246 m/s with the data taken from the oscillogram (no 0114) ΔS_{bz} = 18000 N amounts to f_{dpvII} = 0.0391. And so, as expected the value of the coefficient of principal resistances to motion in a bottom strand of the belt at the increased pretension of the belt increases by about 10%.

When using the same method it is possible to determine the value of the coefficient of principal resistances to motion for a bottom strand of the belt at the belt speed v_I = 1.082 and at normal pretension of the belt. Making use of the data from the oscillogram no 0102 ΔS_{bz} = 12000 N brings about f_{dvI} = 0.0228. This value is slightly higher than the value of the coefficient of principal resistances to motion received for the whole belt conveyor with the aid of utilization of the measured values of active power inputs into the drive.

As f_{dvII} (oscillogram no 0120) has been already determined it is possible to evaluate the coefficient of principal resistances to motion for a top strand of an empty conveyor f_{gvII}. The value of this coefficient is calculated from the relationship

$$P_u = C \cdot g \cdot \left\{f_{dvII} \cdot \left[(L_{ct} - L_c) \cdot q_t + m_{kd}\right] + f_{gvII} \cdot \left(L_c \cdot q_t + m_{kg}\right)\right\} + F_w \text{ N}$$

where P_u stands for the circumferential force on the drive under a steady state motion at a nominal speed. The value of f_{dvII} is 0.0382. The force P_u = 37360 N has been calculated from the active power measured. Substituting the values provides f_{gvII} = 0.0322.

Conclusions and final remarks

The concepts of replacing a number of conveyors used to transport run-of-mine material on horizontal and inclined segments of roads by a long conveyor with a complicated configuration of its route that at present are being accepted in the Polish mining, prove to be suitable and reasonable both in operational and in economic respects. They need, however, working out of design projects to solve problems involved in the operation of the

conveyor. These conveyors improve the work comfort of the belt and drives, what is indicated by the belt conveyor type Gwarek 1000 under testing. The conveyor served for transportation of the whole run-of-mine amounting to about 12500 t per day from the 900 m level to the 1000 m level in the period of three years. It is noticeable that the conveyor is of simple design but meets the assumed requirements.

A correct operation of the belt conveyor being tested and installed on a level and on a slope evidences that it is possible to control the quantity of resistances to motions at the stage of designing the conveyor. A proper selection of a zone of increased resistances to motion and of their quantities is of importance in case of this type of conveyer design.

Increased principal resistances to motion have been stated in the tested conveyor. The resistances are determined by different methods and results of calculations are contained in table 4.

Tab.4. Values of the coefficient f of principal resistances to motion in the Gwarek 1000 belt conveyor.

Quantity of the coefficient f of principal resistances to motion	Value	Oscillogram number	Method of determining
for the whole conveyor and for the belt speed $v_I = 1.082$ m/s	$f_{vI} = 0.0223$	0102	from active power consumption
for the whole conveyor and for the belt speed $v_{II} = 3.246$ m/s	$f_{vII} = 0.0331$	0101	from active power consumption
	$f_{wwvII} = 0.0347$	0116	from force overrun of the belt
for a bottom strand of the belt and for the belt speed $v_I = 1.082$ m/s	$f_{dvI} = 0.0228$	0102	from forces in the belt on turning pulley
for a bottom strand of the belt and for the belt speed $v_{II} = 3.246$ m/s	$f_{dvII} = 0.0364$	0103	from forces in the belt on turning pulley
	$f_{dvII} = 0.0382$	0120	from forces in the belt and from active power consumption
for a bottom strand of the belt for the increased belt tension and for the belt speed $v_{II} = 3.246$ m/s	$f_{dpvII} = 0.0391$	0114	from forces in the belt on turning pulley
for a top strand of the belt and for the belt speed $v_{II} = 3.246$ m/s	$f_{gvII} = 0.0322$	0120	from forces in the belt and from active power consumption

These results confirmed the principle of controlling the resistances to motion in a horizontal and dipping conveyor accepted by the Pioma Mining Machinery Factory. Resistances to motion produced by a convex arc of the conveyor have been recognized to a smaller extent. The table contains values of the coefficient f of principal resistances to motion determined by different methods that approximate values of correct technical calculations. The coefficient f has been for the first time evaluated separately for a top strand and a bottom strand of the conveyor as well as for the conveyor as a whole. The value of the coefficient f for different speeds of the belt and different pretensions of the belt has been also determined. In conformity with expectations the value of the coefficient f for a bottom strand is higher than the value of this coefficient for a top strand and for the whole conveyor. From the tests it appears that the design of this conveyor has an advantageous influence on the service life of the conveyor belt because after three years of intense operation the belt wear was minimum (within 1 mm) whereas the design had an unfavorable affect on the service life of the idler rollers. Replacing of normal idler rollers by reinforced ones resulted in the better condition of the conveyor operated.

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