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INFLUENCE OF CONSTRUCTION THE ROLLERS C TYPE ON RESISTANCE OF ROTATING DRIVEN SYSTEM OF THE BELT CONVEYOR

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Summary

The article presents research related to the rollers construction modification from N-type into C type in the belt conveyor Gwarek 1200 type and the ensuing drop in power consumption measured in the drive unit. The study was conducted in a coal mine at 600 m level of depth. The study also included resistance measurements of static and dynamic rotating rollers in a laboratory stand own construction according to PN-M-46606 standard. The article also presents economic analysis of the C type rollers used instead of N type rollers and profitability analysis basing on 1 ton of coal transport.

Keywords: rollers, belt conveyor, drive power, resistance rotating rollers

WPŁYW KONSTRUKCJI KRĄŻNIKÓW TYPU C NA POBÓR MOCY NAPĘDOWEJ PRZENOŚNIKA TAŚMOWEGO

Streszczenie

W artykule przedstawiono badania związanie z zamianą konstrukcji krążników z typu N na typ C dla przenośniku taśmowym typu Gwarek 1200 i związany z tym spadek poboru mocy pobieranej przez jednostkę napędową tego przenośnika. Badania prowadzone zostały w kopalni węgla kamiennego na poziomie 600m. Przedstawiono również badania oporów obracania się krążników na stanowisku laboratoryjnym własnej konstrukcji zgodnej z normą PN-M-46606. W artykule przedstawiono również krótką analizę ekonomicznej z zastosowanych krążników typu C w miejsce krążników typu N, i jak się to kształtuje w odniesieniu do 1 tony przetransportowanego urobku węgla kamiennego.

Słowa kluczowe: krążniki, przenośnik taśmowy, moc napędowa, opory obracania krążników

1. INTRODUCTION

According to PN-M-46606 L, N or C types rollers are used in belt conveyors [15]. So far, there are no studies on the effect of rollers design N, C and L type at the expense of their purchase (as a result of the tender), replacement costs and regeneration on throughout the life of the belt conveyor. Extractive industry companies do not keep careful register related to exchange and supply of rollers in new or refurbished [4, 5, 12, 14]. This is mainly due to the lack of purposefulness of such records and the influence of such an analysis on the course of mining plant or enterprise, as well as the profitability of employment of the person responsible for keeping such records.

Rollers offered by many specialized manufacturers are not always applied correctly in terms of durability and operational capabilities. This is mainly due to their premature wear as a result of excessive operating conditions for which they were applied [1, 2, 3, 6].

Assuming generally for all belt conveyor (for the entire mining industry in the country) for an average spacing distance rollers in the upper band of 1.25 m (for three-rollers sets) and the lower band of 5 m (for two-rollers sets) and taking the total length of the conveyor belts used in the mining industry that are amount of around 3 million pieces of bearing rollers. [7]. This level is significant when it comes to procurement and operating costs associated with bearing rollers energy costs necessary for overcoming the movement resistance for transporting 1 m^3 of excavated material (in the form of coal or other minerals) [2, 3, 7]. Table 1 presents the amount of rollers used in the mining industry [7].

The amount of rollers included in table 1 shows great potential associated with savings for entire mining industry in case of life service increase and reduce of the resistance for motion of bearing rollers used.

The mining industry is not performing any register relating to the operation time of rollers of the idlers, so it is very difficult to estimate statistical operation time of a roller until its replacement, both of the new rollers and after the regeneration. Manufacturers assume working time of rollers for about 4 years for N type roller, but this is not a consistent information obtained from the laboratory test of N and C type rollers. In terms of mining conditions N type rollers are exchanged even after a month of work, that is different how it's indicated by manufacturers. The research data from Mysłowice - Wesoła coal mine shows, that N type rollers are regularly replaced after half a year of maintenance (with a price of about 70 to 200 PLN per unit of a roller).

Table 1
The length of conveyor belts with the number of rollers used in the mining industry

Manufacturing plant name	Belt conveyors total length[km]	Number of bearing rollers
Coal mines	1 681,0	4 034 880,0
Brown coal mines	250,0	600 000,0
Copper and silver industry	125,0	300 000,0
Minerals mines	84,0	201 600,0
Cement-lime industry	19,0	45 600,0
Total	2 159,0	5 182 080,0

The total number of rollers exchanged in coal industry is about 300 000 units per years. Basing on this data, the following question can be posed: what will be the profits from using C type rollers in place of N type rollers (where according to the PN-M-46606 standard, the C type rollers should be used in the mining industry [17,18,19])?

The mining industry exchanges 639 000 units per years of rollers (coal mines accounts for 290 000 units of rollers, brown coal mines – 180 000 units of rollers, ore mines – 90 000 units of rollers, mines mineral resources of approximately 60 000 units and cement plants – 15 000 units of rollers).

In many cases, the mining business make saving by repairing and regeneration of rollers, which only indirectly reduces costs associated with the purchase of new rollers, but does not count the cost of energy and labour associated with regeneration of worn rollers. But taking into account the entire operation logistics of collection, dismantling, storage or installation the profitability of recovery becomes debatable and questionable [5].

2. PLACE AND METHOD OF N AND C TYPE ROLLERS' TESTING

Research of N and C type rollers was carried out on a idlers of belt conveyor Gwarek 1200-type working at 665 m at level of mining shaft (Table 2). The idlers structure of the route consists of recurring idlers placed every 6 meters. The distance between the idlers of rollers was lg = 1.5 m. Upper belt is carried in a 3 rollers of the idlers with an inclination angle of 30°. Lower rollers are disposed at an angle of 10° to the horizontal level and are composed of two rollers. The distance between the idlers of rollers lower amounts Id = 3m [12].

The rollers applied have a diameter of Φ133mm. The mass of the rotating parts of the rollers 27.6kg. Electrical diagram is shown in figure 1.

Table 2
Technical characteristics of the belt conveyor

Length of the conveyor	L=140m	
Average angle	$\alpha=9^o$	
2-speed gear ratio	i1=25,68	i2=46,96
Linear speed of the belt	V1=3,15m/s	V2=1,6m/s
Power	P=2x90kW	
Efficiency	W1=1200t/h	W2=640t/h
Angle of the trough belt	$\varphi=30^o$	
Tape width	B=1200mm	

3. REQUIREMENTS FOR ROLLERS ACCORDING TO PN-M-46606 STANDARD

According to the PN-M-46606:2010 standard, rollers of the idlers are classified according to the working conditions in which they work. These include light work (marked with L-type), standard work (marked with N-type, hard work (designated with C-type). These terms and conditions of work that divide rollers specified in details. The table 3 show the conditions under which should operate various types of rollers according to the standard [15].

Table 3
The working conditions of L, N, C-type rollers according to the standard [15]

Determination of rollers working conditions	Speed of the belt conveyor [m/s]	Bulk density of transported material [t/m^3]	Maximum size of solids in the conveyed material
L-type light work	<2.5	<0.85	<100
N-type standard work	<2.5	<1.5	<200
	<3.15	<0.85	
C-type hard work	>3.15	>0.8	>200

A light L type roller is designed for conveyors for light conditions of work at low intensity of work and low load. The bearings applied are 6204 2RS or 2z [16]. The bearing has a one outside seal. The standard recommends use of this type of conveyor rollers for transporting the sand, coal and transport materials for construction, particularly for the leads of the lower conveyor belts.

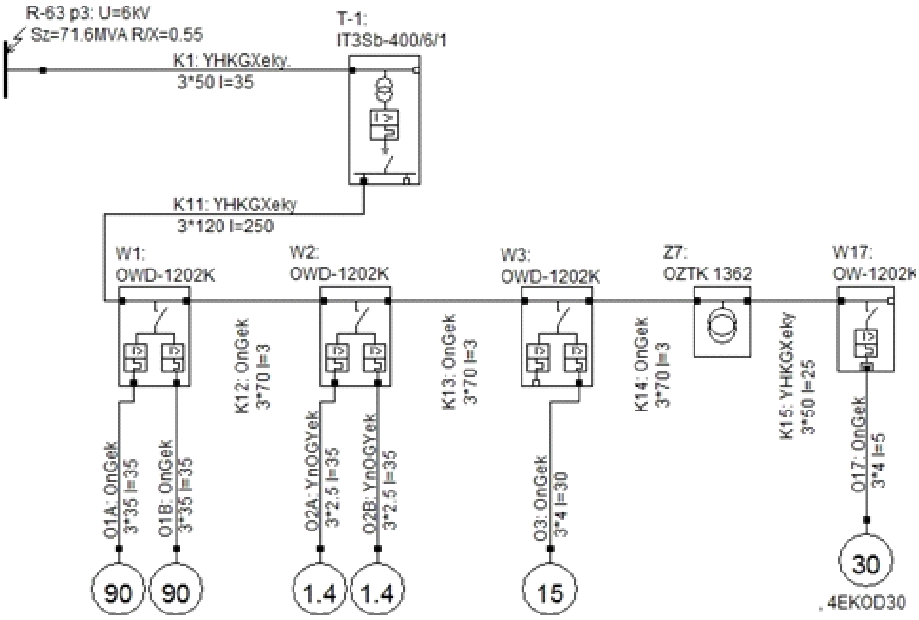

Fig. 1. Electric scheme of analyzed conveyor belt [12]

An N type roller is designed for medium duty conveyors with the belt working in the medium of dust air conditions of work. A roller has a hub crowded-welded type bearings 6305 2RS or 2Z sealed from the outside with one seal. The standard recommends the use of mines (coal, aggregates, sand) to keep the lower conveyor belts. A roller of medium type is built similarly to an L-type roller. The only difference is the use of bearings with higher load capacity and labyrinth seals (Figure 2) [8, 16].

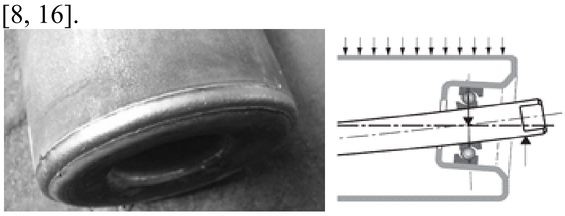

Fig. 2. Construction of N-type roller and geometric changes scheme of N-type rollers under conditions of overloaded work

A heavy C-type roller is designed for heavy duty conveyors working in very dusty conditions and load, these are the conditions that occur in coal mines. The roller has a hub cast-iron bearing type 6305 RS or Z. The bearing is sealed from the outside with three seals, labyrinth seals with a beater or a special seal for heavy rollers (Figure 3) [8]. It is recommended to use mainly in coal, ore or aggregate mines (Table 7) [15].

4. N AND C TYPE ROLLERS TESTING

The mines commonly use N-types rollers because of the price comparing to the C-type rollers which are about 40% more expensive due to quality of execution of production. The rolling testing was carried out according to the following scheme [8, 12, 13, 14, 16]:

1. Measurements of energy consumption in the belt conveyor Gwarek 1200 type at N type rollers (commonly used).
2. Replacement of rollers for C-type rollers.
3. Measurements of energy consumption with three measurement cycles with one-month interval between the measurements.
4. Checking the static and dynamic resistance of rotating rollers of N and C type both before installation and after two months of continuous operation. Measurements of the static resistance of rotating C-type rollers

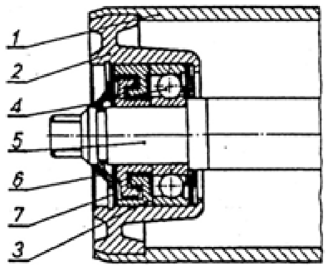

Fig. 3. Construction of C-type roller: 1 – shell, 2 – cast iron hub, 3 – labyrinth seal, 4 – bearing, 5 – axle, 6 – sealing blade, 7 – sealing elastic.

Static resistance measurements of rotating rollers were performed on a testing stand for rollers of own construction [12]. Comparing the results with the recommended in the standard it states that rollers after the trial achieved very high performance of characteristics associated with resistance of the rotation (Table 6).

4.1. Resistance measurements of dynamic resistance of rollers rotation

Measurements of the dynamic resistance of rollers rotation were carried out on a testing stand of own construction, where the axle roller is driven at a fixed of roll shell. The amount of force generated by the stationary roller shell results from to the relative movement of the shell relative to the axis of the roller (Figure 3) [9, 10, 11, 12, 13, 14].

The measurements were carried out for rollers C-type after installation (preceded by 20-minute of stand running-in and further resistance testing after a two-month period of continuous operation. In addition the dynamic resistance were measured of N type rollers rotation which are being standardly used in the belt conveyor Gwarek 1200-type of Mysłowice-Wesoła coal mine after about a year of continuous operation (Figure 4, Table 7).

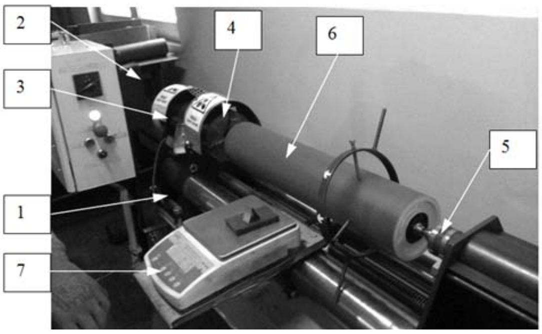

Fig. 4. Testing stand for measuring the dynamic resistance of rollers rotation: 1 – stand base, 2 – stand drive, 3 – belt transmission, 4 –drive worm, 5 – impression roller support, 6 – tested roller, 7 – strength meter

4.2. Researching and analyzing of energy consumption of the belt conveyor Gwarek 1200 type with C-type rollers

The measurements of energy consumption were made on the supply energy of the belt conveyor Gwarek 1200 type. The coal was transported the excavated material to the mine shaft "Karol" at the level of 665 m. The measurement was carried out in the CZU-10 Tr1 IT3Sb 400/6/1 transformer station. The conveyor drive comprises of two electric motors with 90kW power and rotational speed of 1477 rev/min each. Network parameters are: 1000V, 50Hz (Figure 1 [12]).

Power measurement was carried out with the help of Ditch tongs in the voltage box of supply transformer. Power measurement was carried out during the start of the conveyor without spoil and after a few seconds it was flooded from the hopper, to achieve full backfilling at the entire length. The obtained measurement results are shown in table 7.

The study was conducted during three months every 7 days for 60 minutes. In total, the study was carried out for 1260 minutes during normal work of the tested belt conveyor. Actual performance of ore transported was measured by hopper with the possibility of measuring the instantaneous value of the tested conveyor belt performance [12].

5. ANALYSIS OF UNIT ENERGY CONSUMPTION OF THE BELT CONVEYOR GWAREK 1200 TYPE

The conveyor is powered by two induction motors with power:

$$P_n = 2 \cdot 90kW = 180kW \quad (1)$$

The consumption of electricity consumed by the drive system:

$$E = \int_0^{\Delta t} P(t)\, dt \quad \text{for } \Delta t = 60 \text{ min} \quad (2)$$

where:
P(t) – electric power taken from the electricity network.

The total measurement time was 7 intervals of 60 minutes (1h):

$$\sum_{n=1}^{n=7} \Delta t = 1260 \text{ min } (21 \text{ h}) \quad (3)$$

The percentage of conveyor efficiency compared to the nominal capacity is determined according to the formula (4):

$$w = \frac{w_h(t)}{w_n} \cdot 100 \quad (4)$$

where:
w – conveyor capacity in percent,
W_n – conveyor nominal productivity,
W_h – real hourly productivity.

Calculations show that the value of the average performance during the period of time was on average 62.5% compared to the nominal capacity (5):

$$w_{avg} = \frac{\sum w_i(\Delta t_i)}{\sum w_n} \cdot 100 = 62{,}5\% \quad (5)$$

The percentage energy consumption of the network was determined according to the formula (6):

$$e = \frac{E_h(t)}{E_n} \eta_n \cdot 100 \quad (6)$$

The energy requirement related to a power consumed during nominal working conditions of the drive motors for one hour (1h).

Comparing maximum performance with maximum energy consumption with efficiency w_n=100%:

$$e_n = \frac{102}{180} \cdot 100 = 56{,}6\% \quad (7)$$

Table 4

Maximum dimensions of blocks in the transported material in harsh working conditions [15]

Minimum width of the belt B [mm]	The permitted volume of blocks in the transported material (%), on a conveyor belt with rollers designed to work in heavy conditions „C"					
	5	10	20	80	90	100
	Maximum dimensions of lump of coal [mm]					
800	350	300	300	200	200	200
1000	450	400	350	250	250	200
1200	600	500	450	350	300	300
1400-3000	750	650	600	400	350	350

Table 5

The average values of static friction of rotation after running C-type rollers

No.	C-type rollers test	Static moment Ms [Nm]	Range acc. to standard
1.	upper side rollers ϕ133x465	0.020 Nm	0.25-1.00 Nm
2.	upper middle rollers ϕ133x465	0.023 Nm	
3.	bottom rollers ϕ133x670	0.014 Nm	

Table 6

The average values of dynamic resistance for the analysed group of rollers

Parameters	N-type rollers	C-type rollers		Resistance acc. to standard
Time of working in mine	12-month work period	20 minutes of work (running-in)	2 months of work	
Dynamic resistance	2.73 [N]	2.00 [N]	1.09 [N]	3.0-5.0 [N]

Table 7

Measurements results of the conveyor power consumption

No.	Rollers used in the belt conveyor Gwarek 1200 type	Time of work	Type of conveyor work	Power P [kW]
1.	Conveyor work with N-type rollers	after 12 months of work	Transit work -start	139,3
2.			Working in set motion	102,0
3.	Conveyor work with C-type rollers	3 days after mounting on the conveyor	Transit work -start	129,4
4.			Working in set motion	97,5
5.	Conveyor work with C-type rollers	30 days after installation	Transit work -start	96,7
6.			Working in set motion	94,8
7.	Conveyor work with C-type rollers	10 months after installation	Transit work -start	96,0
8.			Working in set motion	93,7

Considering the correlation (7) shows that the conveyor motors operate at 56.6% load. Rated engine power is 53.4%, higher than the power needed to drive the conveyor belt during the period of the study. Energy supply as a result of 53.4% is needed in case of security starting at strewn tape conveyor belt.

These calculations were previously used for N-type rollers in the Gwarek 1200 conveyor. A similar analysis was performed for newly installed C-type rollers. All parameters were also at a similar level of performance during the test. After replacing with the new C-type rollers, the energy consumption was at 52.9% level of the nominal power.

$$e_n = \frac{95,3}{180} \cdot 100 = 52,9\% \tag{8}$$

The analysis also shows that after the exchange on runners of type C, power demand in relation to nominal consumption decreased by 3.7%. Further analysis determined the energy requirement needed for transporting 1 ton ore as a function of efficiency of the tested conveyor:

$$E=f(W) \tag{9}$$

During work of the conveyor with 100% efficiency per unit energy consumption is E/W=0,15kWh/t, while at efficiencies of W=750t/h power consumption of N type rollers amounted E/W=0,136 kWh/t. However, after replacing the rollers into the C type the ratio is E/W=0,127kWh/t.

The calculations above show that during using C type rollers, the power consumption per unit decreases (for the conveyor tested) by 6.6% compared to the N type rollers.

6. CONCLUSIONS

From the above research and analysis shows that the rollers using C-type power unit declined (for the test conveyor) by 6.6% compared to the N-type rollers

Determining the ratio of energy consumption at 100% of the conveyor utilization and its use of the real level of 62.5% of the nominal (assumed by designers), is as follows:

- for N type rollers, changing the power demand per unit decreased by 9.3%,
- for C type rollers, changing the power demand per unit decreased by 15.3%.

It can therefore be concluded that by using C type rollers the unit power consumption is reduced by 6%.

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