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

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 m³ 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).

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

<table>
<thead>
<tr>
<th>Manufacturing plant name</th>
<th>Total length[km]</th>
<th>Number of bearing rollers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal mines</td>
<td>1 681,0</td>
<td>4 034 880,0</td>
</tr>
<tr>
<td>Brown coal mines</td>
<td>250,0</td>
<td>600 000,0</td>
</tr>
<tr>
<td>Copper and silver industry</td>
<td>125,0</td>
<td>300 000,0</td>
</tr>
<tr>
<td>Minerals mines</td>
<td>84,0</td>
<td>201 600,0</td>
</tr>
<tr>
<td>Cement-lime industry</td>
<td>19,0</td>
<td>45 600,0</td>
</tr>
<tr>
<td>Total</td>
<td>2 159,0</td>
<td>5 182 080,0</td>
</tr>
</tbody>
</table>

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 \( l_g = 1.5 \) m. Upper belt is carried in a 3 rollers of the idlers with an inclination angle of \( 30^\circ \). Lower rollers are disposed at an angle of \( 10^\circ \) to the horizontal level and are composed of two rollers. The distance between the idlers of rollers lower amounts \( l_d = 3 \) m [12].

The rollers applied have a diameter of \( \Phi 133 \)mm. The mass of the rotating parts of the rollers 27.6kg.

Electrical diagram is shown in figure 1.

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].

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

<table>
<thead>
<tr>
<th>Determination of rollers working conditions</th>
<th>Speed of the belt conveyor ([\text{m/s}])</th>
<th>Bulk density of transported material ([\text{t/m}^3])</th>
<th>Maximum size of solids in the conveyed material</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-type light work</td>
<td>(&lt;2.5)</td>
<td>(&lt;0.85)</td>
<td>(&lt;100)</td>
</tr>
<tr>
<td>N-type standard work</td>
<td>(&lt;2.5)</td>
<td>(&lt;1.5)</td>
<td>(&lt;200)</td>
</tr>
<tr>
<td>C-type hard work</td>
<td>(&lt;3.15)</td>
<td>(&lt;0.85)</td>
<td>(&lt;200)</td>
</tr>
</tbody>
</table>

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.
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].

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:

$$P_n = 2 \times 90kW = 180kW$$

The consumption of electricity consumed by the drive system:

$$E = \int_{0}^{\Delta t} P(t) \, dt \quad \text{for } \Delta t = 60 \text{ min}$$

where:

$$P(t) \quad \text{electric power taken from the electricity network}$$

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

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

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

$$w = \frac{w_h(t)}{W_n} \times 100$$

where:

$$w \quad \text{conveyor capacity in percent},$$

$$W_n \quad \text{conveyor nominal productivity},$$

$$W_h \quad \text{real hourly productivity}$$

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):

$$w_{avg} = \frac{\sum w_h(\Delta t) \cdot 100}{\sum w_n} = 62.5\%$$

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

$$e = \frac{E(t)}{E_n} \eta_n \cdot 100$$

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 $w_n=100\%$:

$$e_n = \frac{102}{180} \cdot 100 = 56.6\%$$
Table 4

| 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” |
|----------------------------------|---------------------------------------------------------------|
| 800                             | 5                                                                 |
| 1000                            | 10                                                               |
| 1200                            | 20                                                               |
| 1400-3000                       | 80                                                               |
| 1400-3000                       | 90                                                               |
| 1400-3000                       | 100                                                              |

Table 5

<table>
<thead>
<tr>
<th>No.</th>
<th>C-type rollers test</th>
<th>Static moment Ms [Nm]</th>
<th>Range acc. to standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>upper side rollers φ133x465</td>
<td>0.020 Nm</td>
<td>0.25-1.00 Nm</td>
</tr>
<tr>
<td>2.</td>
<td>upper middle rollers φ133x465</td>
<td>0.023 Nm</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>bottom rollers φ133x670</td>
<td>0.014 Nm</td>
<td></td>
</tr>
</tbody>
</table>

Table 6

<table>
<thead>
<tr>
<th>Parameters</th>
<th>N-type rollers</th>
<th>C-type rollers</th>
<th>Resistance acc. to standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of working in mine</td>
<td>12-month work period</td>
<td>20 minutes of work (running-in)</td>
<td>2 months of work</td>
</tr>
<tr>
<td>Dynamic resistance</td>
<td>2.73 [N]</td>
<td>2.00 [N]</td>
<td>1.09 [N]</td>
</tr>
</tbody>
</table>

Table 7

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

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.

\[ e_a = \frac{95.3}{180} \times 100 = 52.9\% \]  \hspace{1cm} (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:

\[ E = f(W) \]  \hspace{1cm} (9)

During work of the conveyor with 100% efficiency per unit energy consumption is \( E/W = 0.15 \text{kWh/t} \), while at efficiencies of \( W = 750 \text{t/h} \)
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=0,127 kWh/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%.

REFERENCES