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ASSESSMENT OF TECHNICAL STATE OF THE BELT CONVEYOR ROLLERS WITH USE VIBROACOUSTICS METHODS – PRELIMINARY STUDIES

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Summary

Most numerous elements in construction of belt conveyors are rollers. From theirs technical state depend the losses of energy among other things on overcome turn resistances of rollers rotation. With point of view of exploitation significant is correct technical state of rollers, which guarantee minimal costs of conveyor work. In the article are present results of preliminary studies, which have on aim non-invasive qualification of technical state of belt conveyor rollers after specified time of exploitation. The measurements of jacket's vibrations of roller installed on laboratory stand were conducted. Next, registered vibration signals were processed. Authors make an assumption, that the comparison of analyses' results for new and wear rollers, allow in next stages of studies determining of limit levels of vibroacoustics phenomena, which exceeding qualify roller to replacement.

Keywords: belt conveyor, vibroacoustics, vibration measurements

OCENA STANU TECHNICZNEGO KRĄŻNIKÓW PRZENOŚNIKÓW TAŚMOWYCH METODAMI WIBROAKUSTYCZNYMI – BADANIA WSTĘPNE

Streszczenie

Najbardziej licznym elementami w konstrukcji przenośników taśmowych są krążniki. Od ich stanu technicznego zależy wielkość strat energii potrzebnej m.in. na pokonywanie oporów obracania krążników. Z punktu widzenia eksploatacji ważny jest więc poprawny stan techniczny krążników, który gwarantuje minimalne koszty pracy przenośnika. W artykule zaprezentowano wyniki wstępnych badań, które mają na celu bezinwazyjne sprawdzenie stanu technicznego krążników przenośnika taśmowego po określonym czasie eksploatacji. W tym celu przeprowadzono pomiary drgań płaszcza krążników montowanych na stanowisku laboratoryjnym. Zarejestrowane sygnały drganiowe poddano następnie przetwarzaniu. Autorzy przyjęli założenie, że porównanie wyników analiz dla krążników nowego i używanych przez różny czas, pozwoli w kolejnych etapach badań określić graniczne poziomy zjawisk wibroakustycznych, których przekroczenie będzie kwalifikowało krążnik do wymiany.

Słowa kluczowe: przenośnik taśmowy, wibroakustyka, pomiary drgań

1. INTRODUCTION

Belt conveyors are the largest group of devices used to continuous transport of many different materials. Its characteristic feature is simple construction. Principal elements their constructions are: going and reversible rollers, rollers which stretch the belt and belt leading rollers.

According to different literature sources, total length of belt conveyors in Poland exceeds 2000 km. The largest application (about 80% of above total length) falls on mining, in which conveyors provides to moving mining. From remaining important branches of industry in which belt conveyors find large application are: heat and power generating plants, metallurgy and the power stations.

Large scale of belt conveyors applications causes the high importance to reduction of costs of their work [7, 10, 16], how also to reliability their construction [15].

The big influence on both of these factors has technical state of the most numerous elements of conveyor that is rollers.

From length of conveyor, the kind of transported material etc., number of rollers can differ significantly, and cost of their replacement can make up the different part in value of whole conveyor [2, 6, 11]. From number of rollers results the energy losses on overcome turn resistances of rollers rotation, also the friction of belt with the jacket of rollers, as well overcome turn resistances of rolling of belt on rollers [1, 2, 5].

Having on attention above, the aim of presented studies was verification of the possibility of determining technical state of rollers with use vibroacoustics methods.

Authors make an assumption, that the comparison of analyses results of vibration signals for new and wear rollers, after specified time of exploitation, allow determining of limit levels of vibroacoustics phenomena, which exceeding qualify rollers to replacement.

For that purpose, on presented stage of studies, the measurements of jacket's vibrations of roller installed on laboratory stand were conducted. Results of measurements are initial part of created database symptoms of rollers in different technical state.

Evaluation of rollers' technical state with use of completed database of symptoms can prevent the exchange of rollers, whose condition allows further exploitation, as well be a basis for a possible an replacement of worn rollers, which, according to the current evaluation criteria, for such an exchange is not yet eligible [3, 5].

2. RESEARCH OBJECT

The research object was rollers of belt conveyor Gwarek 1200. Conveyor works in mine KWK Mysłowice–Wesoła and transporting mining to output shaft on level 665 m. Parameters of research object are listed in table 1 [12, 13].

Table 1
Parameters of belt conveyor Gwarek 1200

Parameter	Value	Unit
Length of conveyor	~ 140	m
Average angle of inclination	9	º
Maximum efficiency of conveyor	1200	t/h
Distance between upper rollers	1,5	m
Distance between bottom rollers	3,0	m

The belt conveyor is driven with two electric engines with 90 kW power every. With attention on number of rollers, assurance of proper their technical state can contribute to lower consumption of necessary energy to drive of belt conveyor.

In construction of conveyor are used rollers with C4 class of seal in bearings as well as the labyrinth seal U4Exp 62/65 with cover 2LU4. In roller are applied bearings 6305 ETN9 / C4, produced by SKF with poliamid basket strengthened with glass fibre [8, 17]. The construction of roller is shown on figure 1.

During research were used four rollers:

- one was delivered new to laboratory direct from producer,
- three rollers were disassembled from belt conveyor working in mine and have visible symptoms of wear.

One from rollers with clearly visible marks of wear of jacket's surface is presented on figure 2.

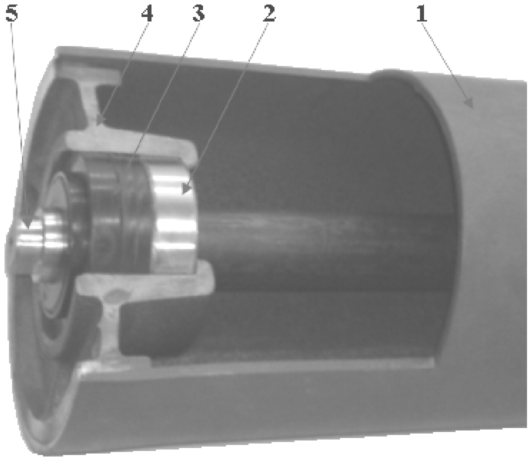

Fig. 1. The construction of belt roller: 1 – jacket, 2 – bearing, 3 – labyrinth seal, 4 – cast iron hub, 5 – axle [12, 13]

Fig. 2. Examined roller with clearly visible marks of wear of jacket's surface

3. RESEARCH PROCEDURE

During studies were measured accelerations of vibration of rollers' jackets in three points. The aim of research was obtaining information on the effects of vibration caused by rolling bearings mounted in roller. Theirs condition directly affects to resistance during rotations.

Rolling bearings are diagnosed in many ways. In laboratories is possible a simple method based on evaluation of residual process – sounds generated during operation of the bearing. The testing method use traditional or electronic stethoscopes. The method of listening is an important drawback – the sense of hearing, and the ability of its perception tends to get used to the processes that occur gradually. Because of that, the method is subjective and not always allow for the proper diagnosis.

Regardless of used equipment, the organoleptic methods are effective only when a specialized person performs a diagnosis. For elimination subjective character, studies were based on more modern methods of bearings' diagnosis. They use for evaluation diagnostic equipment, which record residual processes resulting from the operation of the machine.

In consequence of impossibility of full isolation of the acoustic signal generated by a roller, in particular by its bearings from other noise sources, in tests authors resigned from measurements of changes in sound pressure. This results from the conveyor's work environment. It is characterized with too high noise, in addition with much external interferences from other devices in nearby.

For vibration measurement was used accelerometers PCB M353B15 and PCB M353B16 (ICP standard). Acceleration transducers allow registration of vibrations with frequencies in range 1 Hz to 10 kHz.

Accelerometers were connected to 8–channel data acquisition card EC VibDAQ 8+, which allows to record signals on hard disc of laptop. Card uses 24 –bit/105 kHz A/D converters and offer synchronous sampling for all channels. During the study was made simultaneous measurements of linear accelerations of jacket on the hub bearing.

The signals are sampled at a frequency of 31.25 kHz, which allowed in accordance with the Nyquist criterion for the registration of whole range of vibration acceleration measured by sensors.

Test stand with indicated location of measurements points is presented on figure 3.

The study on presented stage of research took place in laboratory environment, with the reverse method of drive the roller. During operation in normal conditions, that is to say in belt conveyor, axle of roller remains stationary while the jacket rotates. During the measurements jacket was attached in a manner preventing its rotation, while the drive is adjusted to the axle direct from motor rotating at a speed ~650 rpm.

4. EVALUATION OF MEASUREMENTS RESULTS

After signals acquisition was performed signal processing. Analyses were performed in calculation environment Matlab. Taking into account radial cylindrical deviation of rollers' jackets, was made filtration of recorded vibration signals. In result was received the time courses of vibrations caused by the work of the bearings.

In diagnostics of many objects are used simply well-known simple diagnostic measures. Also on this stage of studies, they were used. As will be shown, the value of such measures is determined from simple formula, which makes them very easy to use, also in diagnostic devices.

Some of the measures used in the study are listed below and described in formulas 1-10. The selection of the measures was based on the basis of literature sources and the practical experience of Authors [12, 13, 14]:

- mean square value:

$$\Psi^2 = \lim_{T\to\infty}\frac{1}{T}\int_0^T x^2(t)\,dt \tag{1}$$

where:
T – time averaging [s]

- RMS value:

$$x_{RMS} = \sqrt{\frac{1}{T}\int_0^T x^2(t)\,dt} \tag{2}$$

- variance (the second-order central moment):

$$\upsilon = \lim_{T\to\infty}\frac{1}{T}\int_0^T \left[x(t)-\bar{x}\right]^2 dt \tag{3}$$

- standard deviation:

$$\sigma = \sqrt{\frac{1}{T}\int_0^T \left[x(t)-\bar{x}\right]^2 dt} \tag{4}$$

- peak to peak value:

$$x_{P-P} = \left|\max_{0<t\le T}(x(t)) - \min_{0<t\le T}(x(t))\right| \tag{5}$$

- skewness (the third-order central moment):

$$Sk = \lim_{T\to\infty}\frac{1}{T}\int_0^T \left[x(t)-\bar{x}\right]^3 dt \tag{6}$$

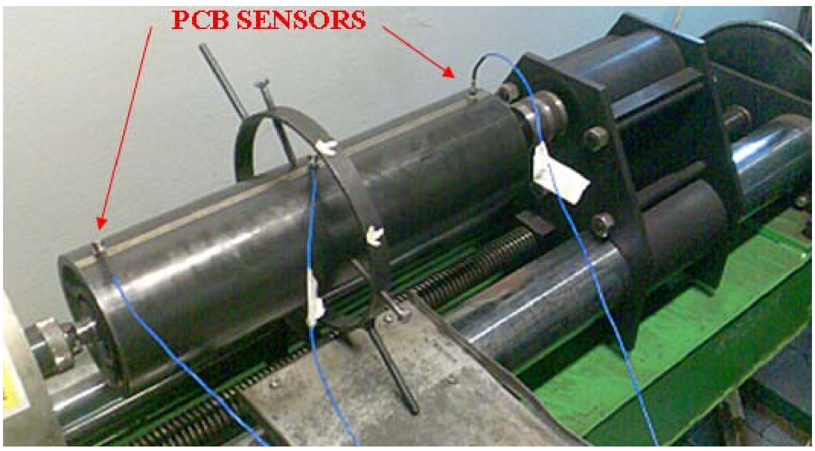

Fig. 3. Test stand with mounted roller and accelerometers

- crest factor

$$C = \frac{x_{P-P}}{x_{RMS}} \tag{7}$$

- waveform factor:

$$K = \frac{x_{RMS}}{\frac{1}{T}\int_0^T |x(t)|\,dt} \tag{8}$$

- clearance factor:

$$L = \frac{x_{P-P}}{\left(\frac{1}{T}\int_0^T \sqrt{|x(t)|}\,dt\right)^2} \tag{9}$$

- impulsivity factor:

$$I = \frac{x_{P-P}}{\frac{1}{T}\int_0^T |x(t)|\,dt} \tag{10}$$

5. SELECTED RESULTS OF STUDIES

Changes in the vibration signal caused by operating wear of bearings mounted in roller, were determined by a number of simple amplitude measurements listed in previous chapter and derived from time courses. Also the time–frequency analysis was carried.

The basic information on the changes in the vibration signal caused by operational wear of rollers deliver RMS values of vibration accelerations. Changes of the RMS value of vibration accelerations of jacket rollers after 9 months of operation $a_{RMS(wear\ roller)}$ related to the value obtained for the new roller $a_{RMS(new\ roller)}$ are presented on figure 4.

The largest increase of RMS value of jacket vibration acceleration of used rollers in relation to the new roller (about 32%) was observed for the third examined roller.

The smallest difference (about 8%) occurred for the first roller. Approximately 24% difference of values obtained for the rollers with the same operation time due, inter alia, from different place of roller installation on the conveyor.

On figure 5 are whereas presented changes of variance values of jacket vibration accelerations $a_{VAR(wear\ roller)}$ related to the value obtained for the new roller $a_{VAR(new\ roller)}$. Figure 6 presents changes of peak to peak values a_{P-P} for tested rollers.

For both measures, nature of changes is similar to changes of RMS value. All of presented amplitude measures are sensitive for change of technical state of tested rollers of belt conveyor.

Next figures (7 to 10) shows changes of values of dimensionless factors: crest factor, waveform factor, clearance factor and impulsivity factor referred to the value obtained for the new roller.

From all dimensionless factors, which are presented, the least sensitivity for wear have waveform factor. For first of tested roller, the change amount only to 1,2%. The best results were received for clearance factor and impulsivity factor.

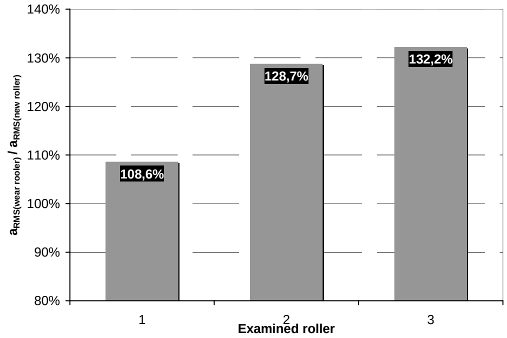

Fig. 4. Changes of RMS values of vibration accelerations of jacket all examined rollers in relation to the acceleration measured for a new roller

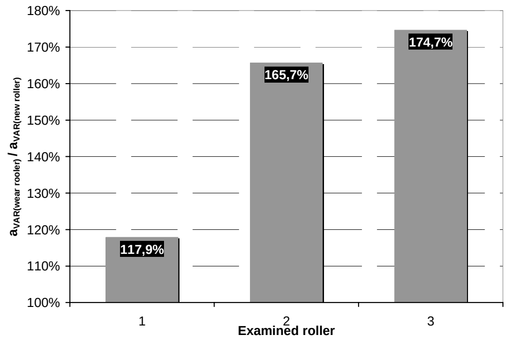

Fig. 5. Changes of variance values of vibration accelerations of jacket all examined rollers in relation to the acceleration measured for a new roller

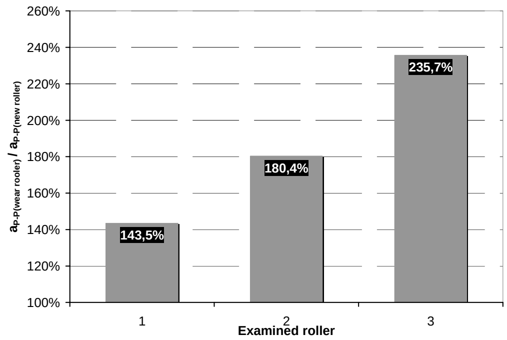

Fig. 6. Changes of peak to peak values of vibration accelerations of jacket all examined rollers in relation to the acceleration measured for a new roller

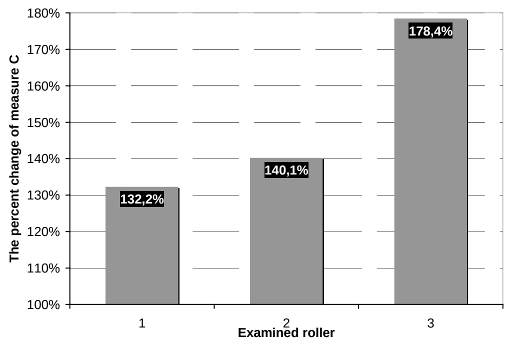

Fig. 7. Changes of crest factor values of vibration accelerations of jacket all examined rollers in relation to the acceleration measured for a new roller

To determine changes in the frequencies components of the registered signals, analysis conducted in the time–frequency domain was performed [4]. Comparison of the spectra obtained for new and wear roller (first examined and showed as '1' on above figures) is shown in figure 11.

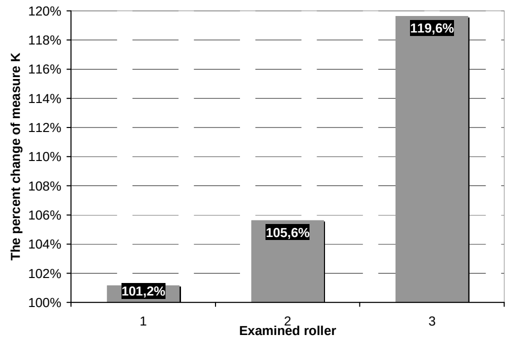

Fig. 8. Changes of waveform factor values of vibration accelerations of jacket all examined rollers in relation to the acceleration measured for a new roller

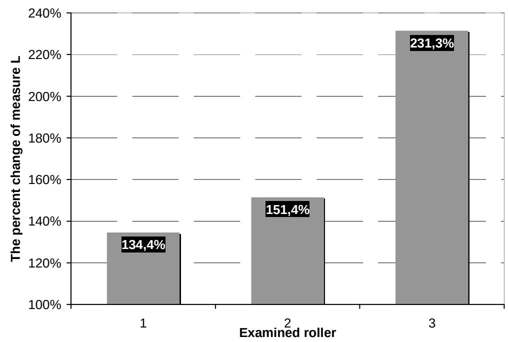

Fig. 9. Changes of clearance factor values of vibration accelerations of jacket all examined rollers in relation to the acceleration measured for a new roller

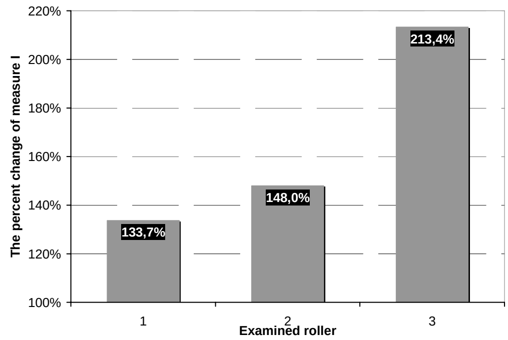

Fig. 10. Changes of impulsivity factor values of vibration accelerations of jacket all examined rollers in relation to the acceleration measured for a new roller

Wear after 9 months of exploitation in mine for each roller caused the appearance in the spectrum of high–amplitude components in the range 6 ÷ 8 kHz. This is most evident in the case of a third of the examined belt roller. For the first roller, in the range 2 ÷ 3 kHz of spectrum are also clearly visible frequency components. Significant difference is visible for low frequencies part of spectrum. For new roller characteristic is component 189 Hz, which have maximal amplitude. For first used examined roller, maximal amplitudes have components with frequencies 145 Hz and 244 Hz.

6. CONCLUSIONS

Wear caused through exploitation affect clearly visible changes of vibration. Changes are visible both in values of simply measures, like RMS value and dimensionless factors. Only waveform factor have too small sensitivity for wear. With use of these measures, service of conveyor can easy detect and control degree of wear.

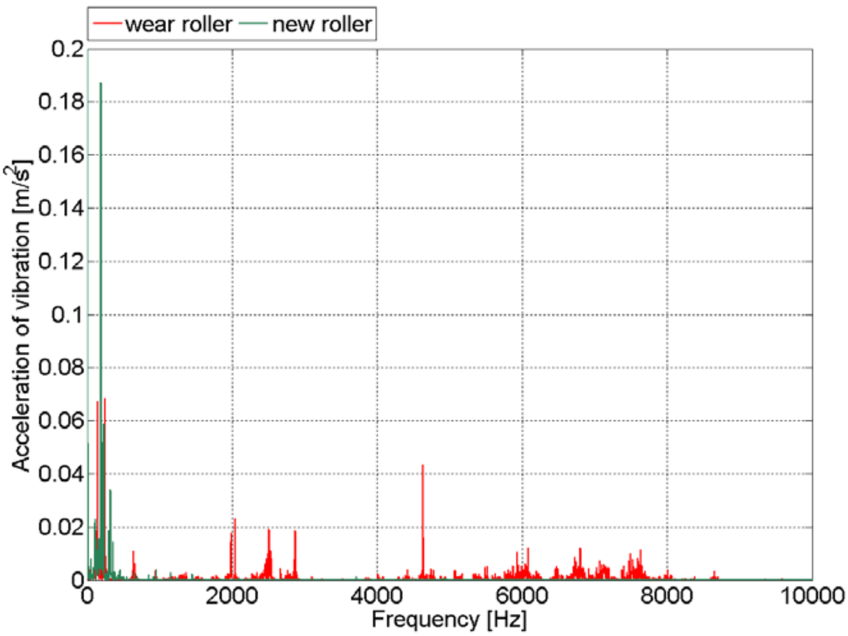

Fig. 11. FFT spectrum of acceleration of vibration signals obtained for the new and one of used roller

More complete picture of changes in the vibration signal provides time–frequency analysis. From the diagnostic point of view, the most useful frequency range is 6 ÷ 8 kHz, wherein in each examined case the essential differences were seen. Further studies are aimed at building measures, which are sensitive on wear of rollers' bearings, based on the results of the vibration signal analysis.

In spite of obtained results, additional laboratory tests carried out on all used rollers has shown that, despite the significant differences seen in the vibration signal caused by the occurrence of wear, they still have a low static and dynamic resistance to rotation (measure methods described in [3, 9, 18]). Small values of resistance were also confirmed by measurements of the energy consumption of the conveyor drive carried out at beginning and after 9-month of rollers' work stages of the research.

For building database of symptoms of rolling technical state, presented research must to be continued until technical state of examined rollers will qualify it to replacement.

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