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Laboratory Tests of Idlers Rotational Resistance – Selected Issues

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Abstract

Idlers rotational resistance has a significant impact on energy consumption of belt conveyors. The conducted analyses showed that this component can account for 30% of total belt conveyor resistance to motion (Gładysiewicz and Kawalec, 2008; Błażej et al. 2013). The causes for idlers rotational resistance including structural factors were precisely determined in (Gładysiewicz and Król, 2005). Since then, many works have been carried out with the aim to assess the quality of idlers and to acquire the knowledge necessary to optimize belt conveyor haulage process (Bukowski et al. 2011a, Gładysiewicz and Król, 2009; 2012). It was due to, inter alia, the fact that the calculations of belt conveyors designs are based only on empirical relationships which give a good approximation for laboratory tested idlers, but are imprecise in relation to new construction solutions of idlers.
The results of research and development works carried out at the Wroclaw University of Technology have shown that one of the conditions for successful reduction of the energy consumption of belt conveyors drives is to use high-quality idlers characterized by low rotational resistance under a wide range of working loads (Bukowski et al. 2011c, Król and Kisielewski 2014). The studies allowed expanding knowledge about idlers rotational resistance and about the impact of working loads on belt conveyors resistance to motion and showed that idlers rotational resistance depends also on value of the idlers radial loads caused by transported masses. A series of laboratory and operational tests based on using advanced analytical tools and modern measuring techniques have been carried out and allowed to observe dependence between instantaneous mass output of belt conveyor and loads of individual idlers in the set. This allowed determining the dependence of idlers rotational resistance as a function of random loading of transported bulk material (Bukowski 2012, Król 2013).

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Keywords: Belt conveyor, idler, measurement, rotational resistance, strain gauge.

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1. Introduction

Increasing lengths of transport routes and varieties of applications necessitate the designing, constructing and operating belt conveyor components with highest possible care. Interruptions or limitations of transported masses stream, which are caused by failure of individual elements of belt conveyor system, result directly in reducing the overall technological process efficiency. Therefore, already during belt conveyor design process, attempts at optimization are made, primarily focused on lowering energy consumption, which is achieved by lowering belt conveyor main resistance (Gładysiewicz et al., 2009). The effectiveness of such actions mainly depends on accurate determination of both random variable service loads and the influence of significant structural features on motion resistance generated in belt conveyor.

The greatest energy consumption reductions may result from adequate belt and idler selection, from optimal spacing of load bearing idler sets, and in some cases also from unconventional solutions used in the design of routes, take-up arrangements and transfer devices (Gładysiewicz, 2003; Król, 2013). In case of high-capacity belt conveyor transportation systems, overcoming idler rotational resistance requires significant amounts of energy. Some analyses show that this component may account for as much as 30% of total motion resistance (Błażej et al., 2013). Rotational resistance of an idler is defined as force applied tangent to idler coat, necessary to overcome friction resistances in its bearings and sealing and can be calculated only on the basis of empirical tests (Król, 2003, Gładysiewicz and Król, 2005). Both the reasons for idler rotational resistance and the influence of structural factors on its level were precisely established (Król, 2003). Extensive research has been performed since and it aimed at investigating idlers quality and expanding knowledge required to optimize the process of bulk material delivery using belt conveyors (Gładysiewicz and Król, 2005; 2006; 2009), in belt conveyor design calculations only empirical relationships are used, which give good approximation for laboratory tested idlers, but appear to be imprecise in relation to new construction solutions. Research results published so far (Bukowski; 2012, Król and Kisielewski, 2014) offer more comprehensive knowledge on idler rotational resistance and on the influence that service loads have on belt conveyor motion resistance. It has been demonstrated that rotational resistance also depends on the value of radial load exerted by the volume of transported bulk. Basic calculations on normative values for rotational resistance or on values for resistance determined as a function of time in accordance with up-to-date norms (PN-M-46606:2010, PN-ISO 1537) caused this component's value to be underestimated. Information thus gathered proved highly valuable in estimating idler durability (Król 2011; 2013) during the process of searching for a solution best suited to user needs from among products commercially offered by many idler producers (Gładysiewicz et al.; 2014) and was also used during the process of implementing energy labels for belt conveyors operating as part of huge transport systems (Kawalec et al.; 2015).

This article presents a method for laboratory tests of loaded idler rotational resistance as well as test results obtained for selected conveyor belt idlers operating in brown coal surface mine and in copper underground mine.

2. Tests of idlers in surface mine

Determination of loaded idler rotational resistance in laboratory conditions, for Ø194x800mm idlers, required a method to be devised which makes use of a strain gauge. The method consists in preparing a measuring bolt, on which a set of foil strain gauges that react to shearing forces is attached with an adhesive. Simple relationships between the measured shearing forces and the moment transmitted to the idler's investigated axle allowed to precisely calculate rotational resistance. The method required bonding full strain gauge bridges to specially prepared flat bolt surfaces and performing calibration so as to enable transition from electric signal expressed in mV into force expressed in N (Fig. 1) (Bukowski; 2012).

Prepared and calibrated measuring bolts were mounted in the openings of the investigated idler's axle journals, the idler was placed on a test rig in which loads can be applied. Fig. 2 shows a test rig devised to measure loaded idler rotational resistance for idlers used in surface mining.

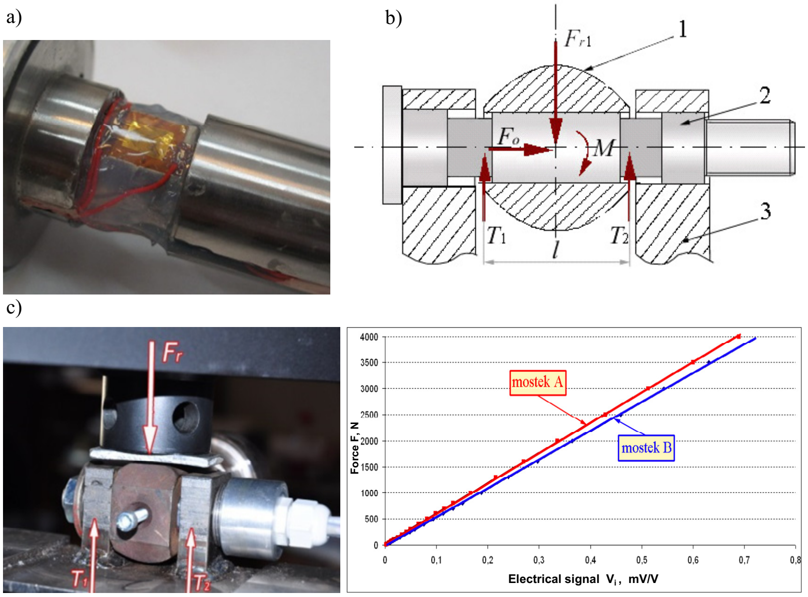


Fig. 1. The idea behind the strain gauge method applied: a) measuring bolt, b) distribution of forces and moment on measuring bolt, c) calibration of measuring bolts.

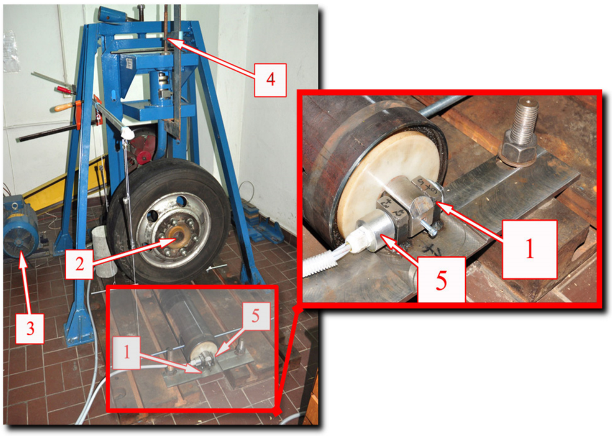


Fig. 2. A test rig for measuring loaded idler rotational resistance: 1 – bracket, 2 – load-exerting wheel, 3 – drive mechanism, 4 – set screw, 5 – measuring bolt.

Three standard idlers and three modernized idlers were subjected to tests in order to establish universal relationships that correspond to design solutions adapted in both cases. Investigation of the influence of radial load on each idler's rotational resistance was performed by assuming radial load F_r levels based on empirically determined radial forces distribution for idlers in load-carrying set (with 1.2 m spacing) depending on mass capacity Q_m for overburden conveyor with belt width B=2.25m (Fig. 3) (Bukowski et al., 2011c).

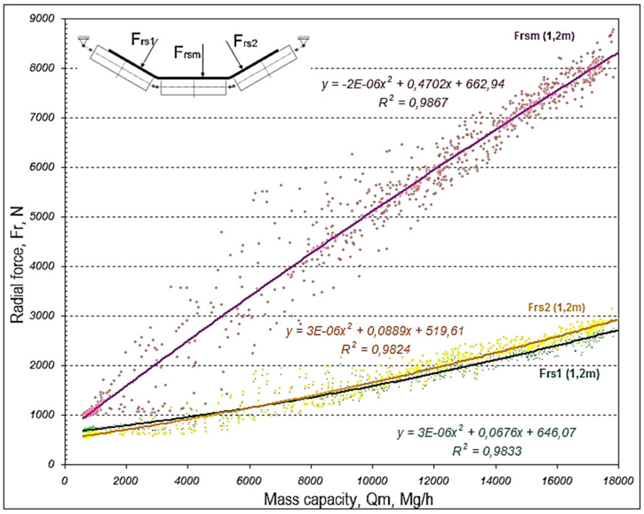


Fig. 3. Radial forces distribution for idlers with 1.2 m spacing depending on mass capacity Q_m.

Averaged results obtained for particular radial load levels provided individual characteristics corresponding to particular tested idler types. Figure 3 shows rotational resistance W_k depending on F_r (calculated into instantaneous bulk material massfor particular idler) along with trend curve (described with quadratic function) serving as interpretation of W_k parameter growth.

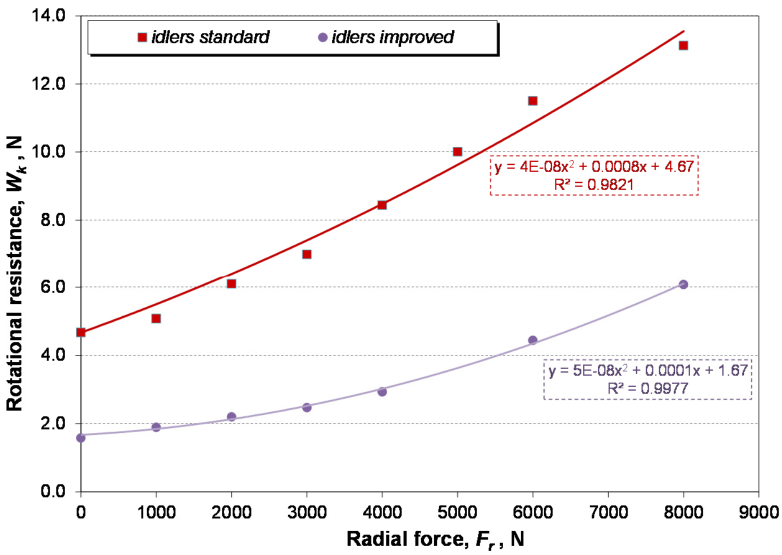


Fig. 4. Rotational resistance to motion of idlers (for overburden conveyors) as a function of their radial loading.

For modernized idlers, significant decrease in the value of rotational resistance W_k was observed across full range of selected loads, which is a direct result of geometry- and material-related modifications of design features. Relationships thus obtained are universal and were used inter alia to estimate energy consumption of belt conveyors used in PGE KWB Bełchatów brown coal mine (Bukowski et al., 2011c; Gładysiewicz and Król, 2012).

3. Tests of idlers in an underground mine

The method presented above was perfectly suitable for large idlers used in surface mines, where the working loads may reach up to 12 kN. In case of idlers used in underground conveyors less complicated methods are available, in which exerting load does not require application of advanced strain gauge methods. Instead, it may be performed with a screw mechanism, while rotational resistance measurements are taken with standard force sensors. Recently published results of research into modernized upper idlers rotational resistance prove such method to be accurate (Furmanik and Kasza, 2013). The idlers were tested using original method according to own invention (Król and Kisielewski, 2014), in which a test rig is utilized to measure rotational resistance, the rig being temporarily (for the purpose of measurements) equipped with additional arrangement exerting radial force on idler coat. Figure 1 schematically shows load application to the idler. Idler coat (1) is provided with additional clamp with wedge groove (12), on which complete frame (13) rests along with a set of weights of a given mass (14). Groove support offers a pivot connection between clamp and frame without transferring additional moments on idler coat. Implementation of screw mechanism (15) allows testing of idlers of various lengths. After weights have been installed and balance position of the frame with weights has been found, measurement system is set to zero. Rotational movement of idler axle (2) causes a reaction on the pan of measuring scale (10) and the readout is further calculated into the value of idler rotational resistance using moment balance conditions and considering lever (9) length and idler radius, from the following equation:

$$W_k = \frac{P_w \cdot g \cdot L_k}{r_p} \tag{1}$$

where:

P_w– mass recorded on scales [kg], L_k– lever length [m],

g – acceleration of gravity [m/s^2], r_p– external radius of idler coat [m].

Figure 5 shows test rig with additional weights.

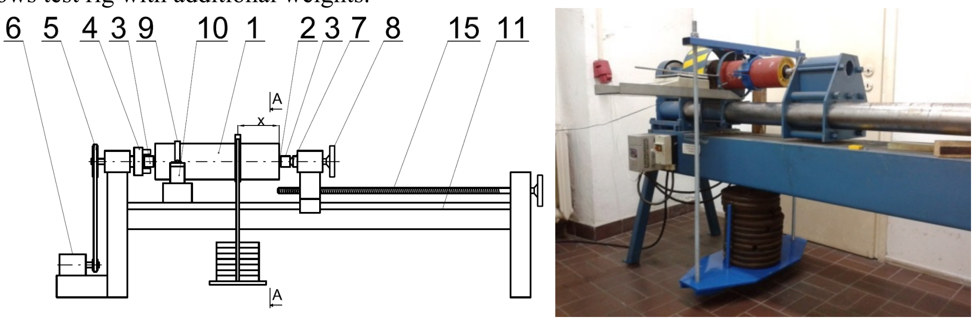
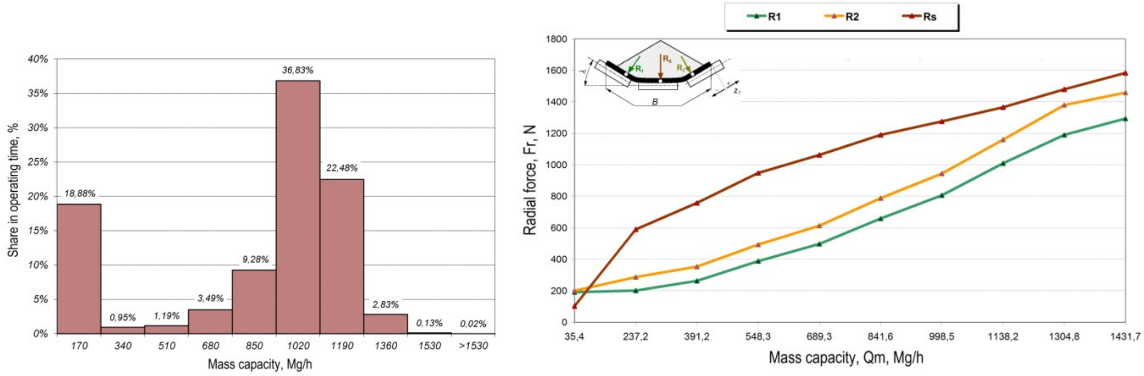


Fig. 5. Measuring of rotational resistance of idler under additional load: a) diagram of rotational resistance test rig, b) view with additional load.

Calculations of the range of radial forces exerted on idler coat in laboratory conditions were performed using QNK-TT software, which aids optimization processes. For a typical main delivery conveyor with belt width B=1.2 m a series of simulations were performed, which allowed to find a relationship between radial load F_r of idlers in the set and the set's instantaneous mass capacity Q_m (Fig. 6b). Information used for that purpose included technical data on LEGMET-type main delivery conveyor and on actual distribution of random variable material stream showed as the mass capacity bar chart (Fig. 6a).



a) b)

Fig. 6. a) Mass capacity bar chart of main delivery conveyor in KGHM underground copper mine, b) distribution of radial forces on idler, dependent on mass capacity of main delivery conveyor.

The presented research method was used in the process of selecting, from among many commercially offered products, an optimal idler that would meet both quality and durability requirements set by users in KGHM Polska Miedź S.A. underground mines (Gładysiewicz et al., 2014). Tests of loaded idler rotational resistance were performed on three load-carrying Ø133x370mm idlers provided by three manufacturers (for the purpose of this paper marked as A, B and C). 9 measurements were performed for each idler to test rotational resistance W_k for each load level and thus to obtain characteristics of rotational resistance depending on radial loading for each individual idler. Figure 7 shows comparison of universal average characteristics for idlers from individual manufacturers along with trend curve serving as interpretation for W_k parameter growth.

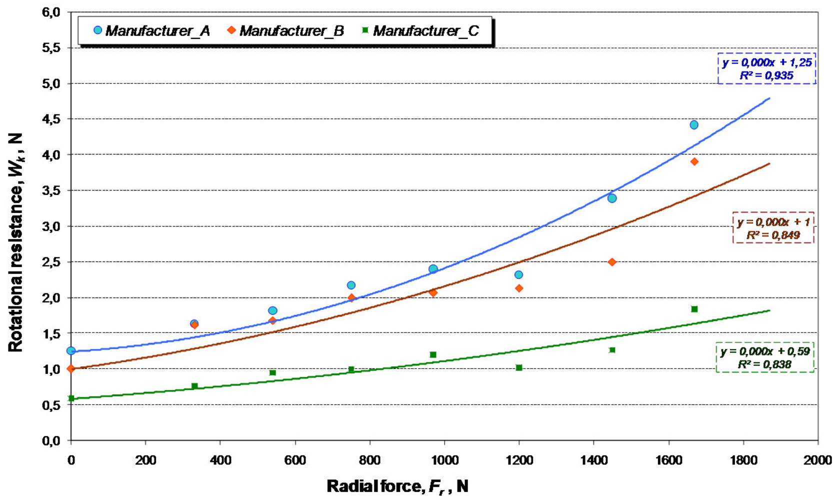


Fig. 7. Average idler rotational resistance depending on radial force, for individual manufacturer (for underground applications).

Values of idler rotational resistance for designs A, B and C are significantly different across the range of service loads. The graph shown in Fig. 4, however, indicates the importance of considering idler wear degree, as differences recorded are even greater than in case of new idlers. The function corresponding to the characteristics of idlers offered by manufacturer C is of particular interest here. It shows very small growth of rotational resistance values, which should translate into significant decrease of belt conveyor resistance to motion.

To show the importance of considering idler wear degree both in calculations of performance parameters for already existing transport systems and in designs of new such systems, and also to aid the implementation of belt conveyor components standardization process using commonly recognized energy efficiency labels (supervised by Wroclaw University of Technology research team), rotational resistance tests were performed on idlers used in an underground copper mine for 1 year.

Fig. 8 shows comparison of characteristics observed for new and used idlers from manufacturer B. Service-life in underground mine conditions significantly decreases idlers quality and recorded differences were even greater than in case of new idlers (Fig. 7).

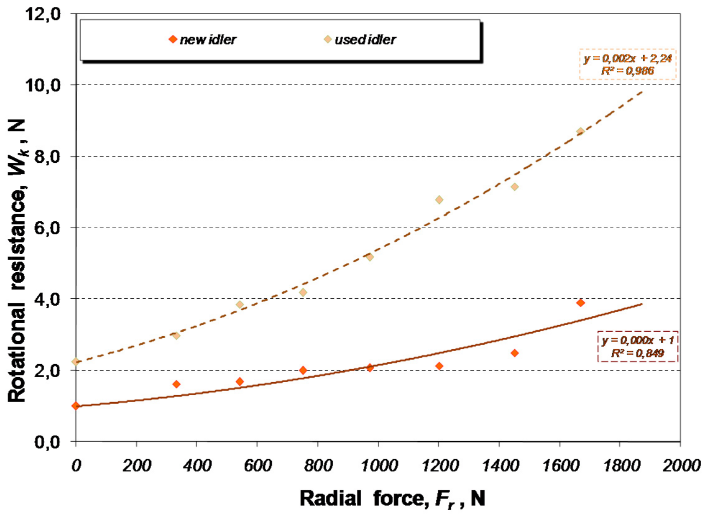


Fig. 8. Rotational resistance to motion of new and used idlers (for underground applications) as a function of their radial loading.

4. Conclusions

This article presents a method for laboratory tests of loaded idler rotational resistance as well as analyses results obtained for selected conveyor belt idlers operating in brown coal surface mine and in copper underground mine. The proposed methods proved effective and served to confirm significant influence of radial force on rotational resistance values recorded for idlers . As a result of performed laboratory tests , individual characteristics for load-carrying idlers were established, which correspond to design solutions implemented (and described as functions). Observations reveal that the type of design solution and wear degree level, which results from idler working time under real operating conditions, have great influence on rotational resistance values across the range of idler service loads.

References

1. Bukowski J., Gładysiewicz L., Kisielewski W., Zur Radialbelastung von Tragrollen, Anlagen - Bauteile - Computersimulationen: 16. Fachtagung Schüttgutfördertechnik 2011, am 14. und 15. September 2011 in Magdeburg, s. 139-152, Magdeburg 2011a
2. Bukowski J., Gładysiewicz L., Kisielewski W., Król R., Operational tests of top idlers. (in Polish: Eksploatacyjne badania obciążeń krążników nośnych), Transport Przemysłowy i Maszyny Robocze, nr 3, s. 46-50, Wrocław 2011b
3. Bukowski J., Gładysiewicz L., Król R., Tests of belt conveyor resistance to motion, Eksploatacja i Niezawodność - Maintenance and Reliability, nr 3, s. 17-25, 2011c
4. Bukowski J., Wpływ obciążeń eksploatacyjnych na opór obracania krążników. (in Polish: Impact of service loads on idler rotational resistance). Doctoral dissertation, Instytut Górnictwa Politechniki Wrocławskie, Wrocław 2012, (unpublished)
5. Furmanik K., Kasza P., Mobile stand for investigation of rolling resistances of unconventional construction idlers. (in Polish: Mobilne stanowisko do badania oporów obracania krążników niekonwencjonalnej konstrukcji.) Transport Przemysłowy i Maszyny Robocze, 1(19)/2013 str.17-20; ISSN 1899-5489
6. Gładysiewicz L., Hardygóra M., Kawalec W., Determining belt resistance, Bulk Handling Today, 2009, vol 5

7. Gładysiewicz L., Kawalec W., The possibilities of decreasing the belt conveyors main drive power demand, Proceedings of the Conference Bulk Europe 2008, Prague, September, 2008 Błażej R., Jurdziak L., Kawalec W., Energy saving solutions for belt conveyors in lignite surface mines. Proceedings of the 13th IAEE European Conference, Duessedorf, August 18-21, 2013.
8. Gładysiewicz L., Kawalec W., Carrying idler spacing with regard to the distribution of conveyed stream. Bulk Solids Europe 2010 : International Conference on Storing, Handling and Transporting Bulk, Glasgow, Scotland, September 9-10, 2010 / Vogel Business Media, Institution of Mechanical Engineers
9. Gładysiewicz L., Król R., Complex assessment of the quality of polyurethane idlers used in surface mining. (in Polish: Kompleksowa ocena jakości krążników poliuretanowych stosowanych w górnictwie odkrywkowym). Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej. Studia i Materiały, 36/2009. ISSN 0370-0798
10. Gładysiewicz L., Król R., Comparison of the quality of idlers used in underground mining. (in Polish: Analiza porównawcza jakości krążników stosowanych w kopalniach podziemnych). Transport przemysłowy nr 1(23)/2006. ISSN 1640-5455, Wrocław 2006
11. Gładysiewicz L., Król R., Kisielewski W.: Experimental studies on the resistance to motion in an overburden belt conveyors system. World of Mining, 6/2012.
12. Gładysiewicz L., Król R., Modernisierung der Tragrollen zur Verringerung des Tragrollenlaufwiderstands. (In English: Modernization of load-carrying idlers aimed at rotational resistance improvement). In: Neue Trends in der Anlagenentwicklung. 10. Fachtagung Schuettgutfoerdertechnik 2005
13. Gładysiewicz L., Król R.: Operational tests of resistance to motion and load of idlers in the belt conveyor.(in Polish: Badania eksploatacyjne oporów ruchu i obciążeń krążników na przenośniku taśmowym). Safety problems in construction and operation of machines and devices used in underground mining: monograph. (in Polish: Problemy bezpieczeństwa w budowie i eksploatacji maszyn i urządzeń górnictwa podziemnego: monografia). 2012, s. 95-107
14. Gładysiewicz L., Przenośniki taśmowe Teoria i obliczenia, Oficyna Wyd. Politechniki Wrocławskiej, Wrocław 2003
15. Gładysiewicz L., Zawilak J., Król R., Kawalec W., Woźniak D., Kisielewski W., Kaszuba D., Parameter specification for belt conveyor new generation components based on studies and laboratory tests. (in Polish: Opracowanie specyfikacji parametrów nowej generacji podzespołów przenośnika taśmowego w oparciu o wyniki prac studialnych i badań laboratoryjnych). Raporty Inst. Gór. PWroc. 2014, Ser. SPR nr 11
16. Kawalec W., Król R., Woźniak D.: A proposal of classification of belt conveyors energy-efectiveness. (in Polish: Propozycja klasyfikacji efektywności energetycznej przenośników taśmowych). Transport Przemysłowy i Maszyny Robocze, 1(27)/2015 str.15-23; ISSN 1899-5489
17. Król R., Evaluation of roller durability for actual loads of belt conveyor. (in Polish: Ocena trwałości krążników dla rzeczywistych obciążeń przenośnika taśmowego). Przegląd Górniczy. 2011, nr 11
18. Król R, Kisielewski W.: The influence of idlers on energy consumption of belt conveyor (in Polish: Wpływ krążników na energochłonność przenośnika taśmowego). Mining Science, 21(2)/2014, s. 61 – 72.
19. Król R., Gładysiewicz L., Wajda A., 2010: Analysis of load distribution for belt conveyor load-carrying idlers. (in Polish: Analiza rozkładu obciążeń krążników nośnych przenośnika taśmowego). Instytut Górnictwa Politechniki Wrocławskiej, Wrocław
20. Król R., Influence of design and operational factors on rotational resistance of idlers used in mining. (in Polish: Wpływ czynników konstrukcyjnych i eksploatacyjnych na opory obracania krążników stosowanych w górnictwie). Doctoral dissertation. Wydział Górniczy Politechniki Wrocławskiej. Wrocław 2003 (unpublished)
21. Król R.: Methods of testing and selection of the belt conveyor equipment with regard to random loading of a transported bulk material (in Polish: Metody badań i doboru elementów przenośnika taśmowego z uwzględnieniem losowo zmiennej strugi urobku).Oficyna Wydawnicza Politechniki Wrocławskiej, 2013
22. Kulinowski P., Simulation studies as the part of an integrated design process dealing with belt conveyor operation, Eksploatacja i Niezawodność - Maintenance and Reliability, 2013, 15 (1)