New Quality Standards of Testing Idlers for Highly Effective Belt Conveyors

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Abstract. The paper presents result of research and analyses carried out into the belt conveyors idlers' rotational resistance which is one of the key factor indicating the quality of idlers. Moreover, idlers' rotational resistance is important factor in total resistance to motion of belt conveyor. The evaluation of the technical condition of belt conveyor idlers is carried out in accordance with actual national and international standards which determine the methodology of measurements and acceptable values of measured idlers' parameters. Requirements defined by the standards, which determine the suitability of idlers to a specific application, despite the development of knowledge on idlers and quality of presently manufactured idlers maintain the same level of parameters values over long periods of time. Nowadays the need to implement new, efficient and economically justified solution for belt conveyor transportation systems characterized by long routes and energy-efficiency is often discussed as one of goals in belt conveyors' future. One of the basic conditions for achieving this goal is to use only carefully selected idlers with low rotational resistance under the full range of operational loads and high durability. Due to this it is necessary to develop new guidelines for evaluation of the technical condition of belt conveyor idlers in accordance with actual standards and perfecting of existing and development of new methods of idlers testing. The changes in particular should concern updating of values of parameters used for evaluation of the technical condition of belt conveyor idlers in relation to belt conveyors' operational challenges and growing demands in terms of belt conveyors' energy efficiency.

1. Introduction
In belt conveyor transportation systems significant amount of energy is used in order to set and keep rotation of idlers. Conducted analyses determined that rotational resistance of idlers can reach up to 30% of total resistance to motion of belt conveyor [1, 2]. The causes of generation of idlers’ rotational resistance with their sensitivity to design and operational features of belt conveyor were precisely determined by Król [3]. The research carried out by the team of researchers from Faculty of Geoengineering, Mining and Geology at Wroclaw University of Science and Technology in the following years with experience from studying operating conditions of belt conveyors [4,5,6,7] resulted in developing specialty procedures and advanced calculation methods gathered together by Król [8]. At the same time members of the same research team started carrying out research into conveyor belt properties due to its large share in total belt conveyor’s resistance to motion and critical importance to safe and stable operation of belt conveyor and the whole transportation system [9,10]. The same team of researchers from Faculty of Geoengineering, Mining and Geology at Wroclaw University of Science and Technology still continuous research into belt conveyors’ resistance to motion, durability
and efficiency. With increasing, at that time, number of idlers manufacturers on the mining equipment market the significant increase in idlers’ quality was observed [11, 12]. Rotational resistance of belt conveyors idlers is still valuable material for both laboratory and analytical research [13, 14] which results in developing new, accurate method of measurements [15].

Laboratory tests of idlers should be done accordingly to standards currently in force (e.g. PN-M-46606:2010, DIN 22112-3, SANS 1313, CEMA 502-2004), which define methodology of tests and acceptable values of measured parameters. Standards tend to keep the same level of defined parameter’s values over extended periods of time. It also should be noted that one of the basic conditions for achieving effects in terms of reducing of belt conveyors drive’s energy consumption is using of idlers with low rotational resistance under full range of working loads [16, 17, 18]. It was proven by research and implementation works carried out in open pit and underground mine conditions [17, 12]. Therefore, proper selection of idlers to be used in new belt conveyors should take into consideration results of research carried out into idler’s rotational resistance under the load. This parameter has not been included in any standard to this day.

Results of research carried out into idlers’ rotational resistance have been successfully used in recent years to properly select idlers to be used in modern belt conveyors [19, 20, 8, 13]. Durability of idlers is a quality feature of idlers which is particularly difficult to estimate during designing of idler. Often idlers’ lifetime in operational conditions is far shorter than the one declared by the manufacturer. Therefore, it is reasonable to extend the requirements for idlers defined by actual standards with idlers durability tests (e.g. with methodology proposed by Król in 2003 [3]). Tests of idlers ‘durability allow to verify the usefulness of certain solution of idler for specific application in long term horizon during the tender procedure stage and should be implemented to actual standards.

Presented changes in the approach to idlers testing and selection allow not only to update the criteria for idlers selection during designing of belt conveyors but will also improve the process of selection of belt conveyors drives with regards to belt conveyor’s primary resistances to motion. The need to implement mentioned changes in standards in force comes mainly from the analyses.

2. Characteristics of selected useful parameters of idlers

Results of all the research into rotational resistance presented in the paper relate to one idler type ø133×380÷465 mm, where ø133 mm is the idler’s shell diameter and 380÷465 is the idler’s shell length. This type of idler is dedicated to being used in underground mines. The main parameter determined during idlers testing is idlers’ rotational resistance. In Polish standard PN-M-46606:2010, which is the base for research results presented in the paper, it is determined on special test stand where the idler’s axle is driven while the idler’s shell is still. For comparison, in the German standard DIN 22112-3 the idler’s shell is driven and exerted with radial force of 250N which is far less than the actual working loads during idler’s normal operation. In general, actual standards contain idlers’ rotational resistance test methodology which do not take into consideration the impact of radial load which exerts on idler’s shell during operation. The main purpose of standard idlers tests is to verify does the rotational resistance value stays below the acceptable value. In case of Polish standard PN-M-46606:2010 the acceptable value of rotational resistance is 4.5 N. Results of idlers’ rotational resistance tests carried in 2001 for series of idlers from one manufacturer show that in that time there were some difficulties in keeping the rotational resistance value within acceptable range. As shown in the Figure 140% of tested idlers had the rotational resistance value higher than the acceptable 4.5N which allowed to qualify the whole series as not meeting the PN-M-46606:2010 standard requirements.
Figure 1. The graph presents the results of rotational resistance tests carried out for series of idlers from one manufacturer in 2001 [21].

Since the year 2000 systematic idlers test were started at the Faculty of Geoengineering, Mining and Geology at Wroclaw University of Science and Technology. Along with each new test the knowledge on how to improve idlers quality was gained and afterwards popularized through publications and conference presentations. Nowadays idlers are characterized by the rotational resistance value significantly lower that in 2001 and at the same time much lower that the acceptable value in standards in force. Interesting is that the rotational resistance of idler at the level of 1N a less is nowadays commonly achievable (Figure 2).

Figure 2. Comparison of rotational resistances values for idlers from five manufacturers actually available at the idlers market.

In PhD dissertation of Bukowski [20] it was shown that the idlers’ rotational resistance strongly depends on radial load excerpted on idler’s shell (figure 3), and in the range of low radial loads the dependence is mild when in the range of high loads (reaching maximum load exerting on idler’s shell...
during work in operational conditions) the dependence is strong and the rotational resistance strongly increases with the load increase.

**Figure 3.** Exemplary dependence of idler’s rotational resistance on radial load [20]

The nature of increase of idlers’ rotational resistance as function of radial load strongly depends on idlers' design features. Therefore, the new parameter in idlers testing was developed which is the characteristic of radial load impact of idlers’ rotational resistance. This parameter was utilized in the process of selection of idlers to be used in prototype belt conveyors with reduced energy consumption dedicated to operate in underground copper ore mines. For this purpose, carry idlers from three separate manufacturers were tested on specially designed and manufactured test stand (Granted Patent PL225574) to determine the rotational resistance under the load. Moreover, used idlers made by manufacturer B dismounted from belt conveyor operating in underground copper ore mine were also tested. Results of tests of analyzed idlers are shown in the Figure 4. From the comparison of the results it is clearly visible that all three manufacturers produce idlers with rotational resistance values very similar to each other. Differences in rotational resistance between idlers from different manufacturers become clearer when the rotational resistance under the radial load is compared. It is worth to notice because the rotational resistance during belt conveyor operation depends on random loading of a transported bulk material stream.

**Figure 4.** Determined dependences of idlers’ rotational resistance on radial load for analyzed idlers
When idlers which known dependence of rotational resistance on radial load are analyzed in order to be installed on specific belt conveyor with known random loading of a transported bulk material stream then it is possible to calculate the average rotational resistance of single three idler set (carry set) with random operational loads taken into account. It allows to select idlers which are the best match for certain application. The procedure of determining average rotational resistance for three idler set requires to determine the rotational resistance for all idlers separately for each level of loading (radial load) possible in analyzed application. The average rotational resistance can be determined:

\[
\bar{W} = \sum_{i=1}^{n} \left[ (W_m + W_{s1} + W_{s2}) \cdot p_i \right]
\]

where: \(n\) – number of mass capacity classes, \(W_m\) – rotational resistance under the load determined for middle idler, \(W_{s1}\) and \(W_{s2}\) – rotational resistance under the load determined for side idlers (can be different), \(p_i\) – probability of occurrence of \(i^{th}\) mass capacity class.

During selection of idlers for the prototype belt conveyor with reduced energy consumption for underground copper ore mine carry idlers from three manufacturers were analyzed and compared to used (standard) idlers dismounted from belt conveyor operating in underground copper ore conditions. Determined values of average rotational resistance for the single three idler set (carry set) are shown in the Figure 5. It is clearly visible that the average rotational resistance value for idlers from manufacturer 3 are more than three times lower when compared to standard idlers and significantly lower than idlers from other manufacturers.

![Figure 5. The average rotational resistance for analyzed three idler carry sets](image)

Other important parameter of idlers is durability. Twenty years ago, it was thought that low durability of idlers is caused by high mass unbalance. It was also taught that the low quality of steel pipes used for idler’s shell is the main cause to idler’s mass unbalance. Also, the opinion that required mass unbalance class (for analyzed idlers acceptable unbalance class is G40) can be reached only with use of calibrated steel pipes for idlers shells was widely popular back then. At present at the market there are rolled intermediate product available from which it is possible to produce idlers characterized by low radial runout and low mass unbalance. Renowned idlers manufacturers verify quality of produced idlers on regularly. This results in high quality of produced idlers. Figure 6 shows the share of unbalance classes G6.3, G16 and G40 for idlers produced by different manufacturers. It can be observed that all idlers meet the acceptable unbalance requirements. Moreover, it can be observed that all idlers from manufacturer D are characterized by the best unbalance class G6.3 when all idlers from manufacturer E are characterized by highest acceptable unbalance class G40.
Knowledge on forecasted durability of idlers is very important during design process of belt conveyors especially when newly designed idlers are meant to be installed. If there are no information on how the idlers of new type will behave in operational conditions, then it is possible to use laboratory accelerated wear test method. In this method idler is being subjected to values of radial load and rotational speed which significantly exceed the actual operational values. Therefore, 7 hours of laboratory test are equivalent of one year of working under the operational load and rotational speed. This way the increased wear is achieved in laboratory conditions (figure 7).

Laboratory test stand for accelerated wear test can be also used to determine idler’s’ seals tightness for dust and water. The final results of accelerated wear test are rotational resistances of idlers determined for consecutive years of idler’s operation simulated in laboratory conditions (figure 8), e.g. during 35 hours of laboratory test 5 years of operation is simulated.
Idlers produced by manufacturers A and D are characterized by stable rotational resistance during entire test time. It can be assumed that after 5 years of operation idlers from manufacturer A and D will not show the signs of increased wear. Idlers from manufacturer A and D can be recommended to be used in energy efficient belt conveyors. Results obtained for idlers from other manufacturers show general increase in value of idler’s rotational resistance with each simulated year. It is also clear that idlers produced by manufacturer E will have significantly lower durability than idlers from manufacturers A or B. It is worth noticing that after 5 years of simulated operation all tested idlers are characterized by rotational resistance value within acceptable range which is under 4.5N. Moreover, manufacturers’ A and D idlers’ rotational resistance value is approximately 0.5N after 5 years of simulated operation.

3. Conclusions and recommendations

Results shown in the paper present the progress in idlers’ quality made since the need of testing idlers useful parameters was popularized. Idlers should be regularly tested by manufacturers to maintain control oved idlers’ quality and to assess implemented design modifications on idlers’ quality. Moreover, idlers should be also tested by their users to assess their usefulness for specific application.

Proper selection of idlers of the basis of presented research results should first consider requirements included in standards in force e.g. PN-M-46606:2010 or its equivalents. Requirements of standards in force were high twenty years ago. Nowadays technological progress and research results allow to produce idlers far superior that 20 years ago, which are characterized by rotational resistance value that is couple times lower than acceptable value in actual standards. Thus, it is necessary to develop new, adjusted to modern idlers, acceptable values of idlers’ rotational resistance. Moreover, nowadays it is possible to produce high quality idlers characterized by low mass unbalance (e.g. G6.3) and high durability (5 years and more). This will most likely apply not only to idlers type $\phi$133×380÷465 but also to other types of idlers.

Radial load is important parameter in case of rotational resistance’s value. For idlers type $\phi$133×380÷465 characterized by high quality the rotational resistance value’s increase from no radial load to maximum radial load should not exceed 1.5N for the idler to be called energy efficient.
During design process or modernization of belt conveyors for the purpose of idlers selection it is reasonable to use idlers’ characteristics including the impact of radial load on idlers’ rotational resistance and to choose idlers on the basis of average rotational resistance which takes into consideration the impact of full range of operational loads of idlers’ rotational resistance. It is the guarantee to mate the optimal choice for a specific application.

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