Journal of Sustainable Mining
ISSN 2300-3960
The English-language online version (primary, reference version of *J. Sust. Min.*)

J. Sust. Min. Vol. 12, (2013), No. 3, pp. 1–7

JOURNAL HOMEPAGE
jsm.gig.eu

http://dx.medra.org/10.7424/jsm130301

Received: 2013.05.24 | **Accepted**: 2013.08.23 | **Available online**: 2013.09.06

DURABILITY TESTING OF IDLERS FOR BELT CONVEYORS

Andrzej Pytlik

Department of Mechanical Devices Testing, Central Mining Institute (Katowice, Poland)
Corresponding author: apytlik@gig.eu, tel. +48 32 259 22 24, mob. +48 512 293 840, fax: +48 32 259 65 33

Abstract
The main purpose of idlers is to provide the correct shaping, support and protection of a belt conveyor, reduce motion resistance as well as support for transported materials.
The durability of idlers depends on numerous construction, engineering and operational factors. In practice, the idler bearings are often damaged due to wear and tear, jamming or seizure and the calculated durability does not comply with the actual lifetime of a bearing (Antoniak 2007).
According to laboratory and operational practices, the quality of currently manufactured standard idlers is low and their average durability is approximately one year (Gładysiewicz, Orzeł, Noga 2012).
Idlers do not meet the requirements specified in the PN-M-46606:2010 standard, even at the stage of their production, which is confirmed by tests carried out in the Department of Mechanical Devices Testing – the Central Mining Institute (GIG).
Taking the above into consideration, testing stands which allow the testing of static and dynamic resistance of idlers' movements as well as stands for examing the idlers' water-tightness and dust-tightness in accordance with the PN-M-46606:2010 standard have been designed and constructed in the Department of Mechanical Devices Testing – the Central Mining Institute. The abovementioned testing stands were extended with additional functions, with regard to the above specified standard, facilitating the measurement of the temperature of bearing assemblies and to test the influence of rotational speed and idler loading in regards to durability.
The tests were carried out on idlers with diameters of ϕ133 and ϕ159 mm, with a bearing assembly equipped with a single-raw ball-bearing. A newly developed type of hybrid seal (labyrinth-lip), registered in the Patent Office of the Republic of Poland under the number W.121582 on 17 December 2012 (Pytlik, Rabsztyn 2012), was used in the idler with the diameter of ϕ133. A typical labyrinth seal was used in the idler with the diameter of ϕ159.
On the basis of the durability tests carried out on both of these idlers it can be concluded that the applied research methodology describes the test conditions of idlers, in a manner as close as possible to their actual operational conditions, which were subject to a variety of factors for a total time of 116 hours, they included: dust, water, loads and variable rotational speed. This methodology allowed us to determine, even at the stage of laboratory tests, the suitability of a particular idler to certain operational conditions.

Keywords
belt conveyor; idler; testing stands; durability

1. INTRODUCTION

The main purpose of idlers is the correct shaping, support and protection of a belt, the reduction of motion resistance of a belt conveyor as well as the support of the transported material. The bearing mounting in carrying idlers consists of a proper inner-bearing mounting of the idler hub which rotates around a stationary axis. Ball bearings are mainly used for bearing mounting. The nominal fatigue durability of an idler ball bearing, with the statistical reliability of 90%, is determined on the basis of a calculation method. Fatigue durability amounts from 5000 h to 15000 h (from 1.2 to 3.6 years when 16 operating hours a day), depending on the operating conditions, however not more than the wear life of the bearing resulting from its impurity. If the bearing load and the number of revolutions are known, the fatigue durability factor for the planned durability (from 3 to 4.5 years for mining belt conveyors) can be determined based on the tables provided by the bearing manufacturer in their sales catalogue and subsequently the load-bearing capacity can be calculated and then the most suitable type of idler hub can be selected. The durability of the idlers depends on numerous construction, engineering and operational factors. In practice, the idler bearings are often damaged due to wear and tear, jamming or seizure and the calculated durability does not comply with the actual useful life of that bearing (Antoniak 2007).

According to the PN-M-46606:2010 Polish standard, the calculated durability of the bearings adopted in the design of idlers should be not lower than 20000 h of operation at a speed of 600 rpm.

The durability of bearings is the decisive factor which influences the durability of idlers for belt conveyors. A typical design solution of an idler is presented in Figure 1 below.

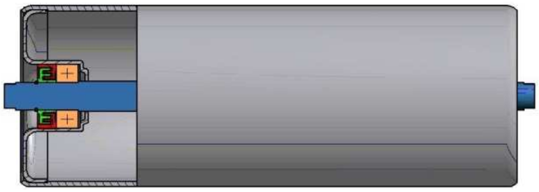

Fig. 1. Smooth idler for a belt conveyor with a labyrinth seal

Seals extend the durability of bearings. Currently, clearance seals are mainly used (Marcinkowski, Kondura 2008 (in particular labyrinth seals), made of flame-resistant plastics. Figure 2 below presents an exemplary design of a typical labyrinth seal.

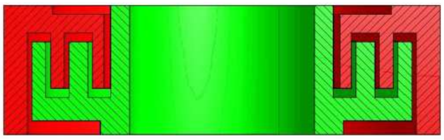

Fig. 2. Typical design of a labyrinth seal

According to the results of a test on idler sealings carried out by the Department of Mechanical Devices Testing of the Central Mining Institute (Pytlik et al. 2012), they do not ensure proper water-tightness but, nevertheless they are sufficient for an effective protection against dust, provided that a suitable coupling grease, which guarantees a long-term adhesion to the labyrinth walls is used.

In practice, the manufacturers of idlers also use contact seals, e.g. lip seals which are very sensitive to impurities penetrating between the axis of an idler and the sealing lip and it often results in a significant rotation of an idler's resistance which as a consequence leads to an increase in the temperature of the bearing assembly and this, in extreme cases, can cause a self-ignition of a conveyors belt.

Laboratory and operational practices result in low quality and low average durability (ca. one year) (Gładysiewicz, Orzeł, Noga 2012) of currently manufactured standards.

Even at the stage of their production, as is confirmed by the tests carried out in the Department of Mechanical Devices Testing of the Central Mining Institute, idlers do not meet the requirements of the Polish PN-M-46606:2010 standard.

Taking the above into consideration, the testing bench that facilitates the testing of static and dynamic resistance of idler movements as well as the bench testing of idlers' water-tightness and dust-tightness in accordance with the Polish PN-M-46606:2010 standard have been designed and built in the Department of Mechanical Devices Testing of the Central Mining Institute. The abovementioned testing bench was extended with additional functions in regard to the above specified standard, to facilitate measuring the temperature of bearing assemblies and to test the influence of the rotational speed and the loading of the idler on its durability.

2. OBJECTIVES OF TESTING

The purpose of this study was to develop a methodology for determining the durability of bearing assemblies and the expansion of the existing testing bench necessary to carry out tests on idler durability and the preliminary test of selected types of idlers.

3. SCOPE OF TESTS

For the purpose of this study:

- a methodology for testing idler durability was developed
- the existing testing bench has been expanded for the testing of idler durability
- preliminary tests on idler durability were carried out

During the tests, carried out in accordance with the standard, the following parameters and factors were determined:

- static and dynamic idler resistance to movement
- dust-tightness and water-tightness

Beyond the scope of the standard, an increase of temperature of bearing assemblies during operation as well as the influence of rotational speed and idler load on the value of dynamic rotation resistance were determined.

The tests were carried out on the idlers with diameters of ϕ133 and ϕ159 mm, with a bearing assembly equipped with a single-raw ball-bearing. A new type of hybrid seal was used in the idler with the diameter of ϕ133 (labyrinth-lip) – developed and registered in the Patent Office of the Republic of Poland under the number W.121582 on 17 December 2012 (Pytlik, Rabsztyn 2012), presented in Figure 3. A typical labyrinth seal shown in Figure 2 has been used in the idler with the diameter of ϕ159, presented in Figure 1.

Fig. 3. Bearing assembly with a new seal in accordance with the invention of the Central Mining Institute no. W.121582 (Pytlik, Rabsztyn 2012)

4. TEST METHODOLOGY

Monitoring the work of idlers in operational conditions led experts from the Silesian University of Technology in Gliwice to the conclusion that (Antoniak 2007) the damage symptoms of an idler do not coincide with each other because there are some idlers where: the damage is manifested by an increase in temperature, or noise is emitted into the environment or they vibrate. No rule was found because mostly only one symptom occurred and statistically the most frequent was an increase in temperature.

Based on years of research concerning the testing of idlers in laboratory conditions and research concerning repair and maintenance management in mines, the team of researchers from the Wrocław University of Technology described in an article (Król, Jurdziak, Gładysiewicz 2008), that the basic relationship combining the operation time of an idler and the increase of temperature in the bearing assembly is the main parameter for indicating the technical condition of the idler. A review of the literature with regards to the subject led the authors of the article to a document written by I.R. Riley [1994], where idler evaluation was made on the basis of the following values of their operational temperature:

- above 5°C in excess of the temperature of the environment – the idler is defective and should be replaced after 3 weeks

- above 15°C in excess of the temperature of the environment – the idler should be considered unrepairable and it should be replaced immediately

After tests undertaken in KWB Turów and KWB Konin open-pit lignite coal mines, the authors of this article determined the criterion for the evaluation of thermal idler conditions according to the following formula:

$$T_{dop} = T_{ot} + 25, \text{°C}$$

where:

T_{dop} – allowable temperature, °C
T_{ot} – environmental temperature, °C

A similar criterial value of temperature increase in relation to the abovementioned criterion is presented by Gładysiewicz [2003], in which it was assumed that the idlers of the conveyor belt were in good technical condition when they are running and did not show any increase of temperature by over 20°C in relation to the environmental temperature.

The methodology of testing the durability of idlers for belt conveyors on the Central Mining Institute's stand is based on the following sequence of tests described in the Polish PN-M-46606:2010 standard:

A. dust-tightness – 72 h, on the stand according to the diagram presented in Figure 4

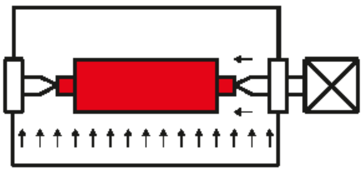

Fig. 4. Diagram of the testing stand for testing the dust-tightness of an idler

- 1.5 kg of industrial talcum powder is poured to the chamber with a capacity of 0.75 m^3.
- The chamber is closed and then the talcum is sprayed through the activation of the internal fan.
- The same talcum should not be used for more than 20 tests.
- After about a minute, the fan is turned off and the idler is inserted into the chamber.
- The compressor is turned on for 1 minute as well as the internal fan. The compressor is turned on for one minute approximately every 4 hours.
- The test is carried out for 72 hours in two stages. At the first stage, the idler is rotated at a speed of 600 rpm for 48 hours. During the second stage, the idler does not move for 24 hours.

B. Water-tightness – 36 h, on the stand according to the diagram presented in Figure 5.

- The tested idler is placed on the testing stand so that the idler's axis is between the centre points.
- The chambers with the shower strainers which spatter water are placed at both ends of the idler, inclined at an angle of approximately 45º to the idler's axis. The strainers should be fixed so that the distance from the head surface of the idler's sealing systems is approximately 200 mm.
- The test is carried out for 36 hours in two stages. During the first stage, the idler is rotated at a rotational speed of 600 rpm for 24 h. During the second stage, the idler does not move for 12 hours. The idler is rotated every 3 hours by 90º, so that the main water stream affects the whole perimeter of the sealing system.

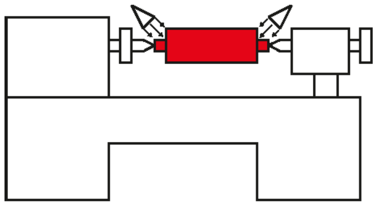

Fig. 5. Diagram of the testing stand which tests the water-tightness of the idler

C. Durability test of the idler under load – 4 h, on the stand according to the diagram presented in Figure 6.

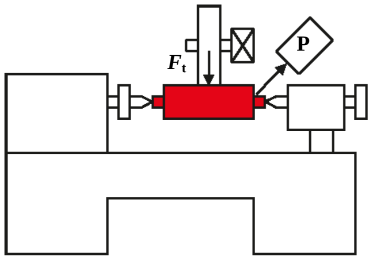

Fig. 6. Diagram of the testing stand which tests the durability of the idler under load

- A drive wheel with an engine and weights, which load the tested idler with the total force of approximately F_t = 250 N, is installed on the idler which is then placed in the testing stand so that the idler's axis is between the centre points.
- Subsequently, the shell of the idler is brought into rotational motion at a rotational speed of 600 rpm for 4 h.

D. Testing the dynamic resistance of the idler's rotation at a rotational speed of 600 rpm and the measurement of the temperature of the bearing assembly by means of a pyrometer – 4 h, is carried out on the stand according to the diagram in Figure 7. Regarding the temperature criterion, the following formula has been adopted:

$$T_{dop} = T_{ot} + 25, \text{°C}$$

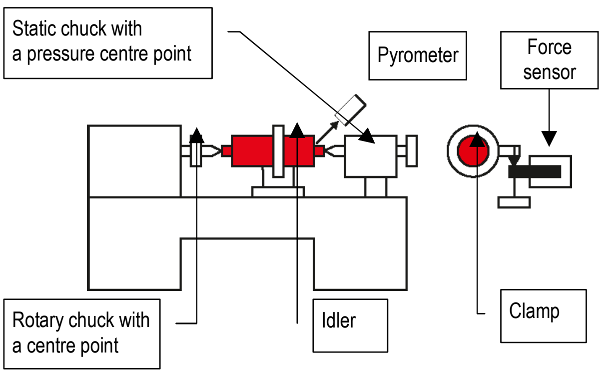

Fig. 7. Diagram of the testing stand which tests static and dynamic movement resistance of the idlers for belt conveyors

E. dynamic resistance test at various rotational speeds in the range from ca. 30 to 600 rpm in order to determine the dependency of dynamic resistance in the idler's rotational speed function, carried out on the stand according to the diagram in Figure 7.

- A clamp adjusted to the idler diameter is placed on the tested idler and then the idler is placed in the testing stand so that the axis of the idler is between the centre points.
- A tensometric force sensor (Z6FC3) is fixed to the clamp together with a fixing element.
- Afterwards, the axis is brought into rotational motion at a rotational speed in the range from 30 to 600 rpm for about 1 minute.

Dynamic resistance of the idler's rotation F_O, expressed in Newtons, is calculated according to the following formula:

$$F_O = 2Fl/d, \text{ [N]}$$

where:

F – average readings of the force sensor recorded during 60 seconds, N

l – length of the arm on which the force acts (marked on the clamp), mm

d – external diameter of the idler, mm

Acceptable values of dynamic rotation resistance are given in the subject standard PN-M-46606:2010. The acceptable dynamic rotation resistance F_{dop} for smooth idlers with diameters of ϕ133 and ϕ159 mm is 4.5 N.

Tests of dynamic rotation resistance at a rotational speed of 600 rpm generates the predominant frequency in the measurement spectrum; 10 Hz. For this reason, in order to ensure the accurate transfer of the force signal in the bandwidth to 10 Hz, according to the Nyquist rule in signal sampling, the sampling frequency should be at least 20 Hz.

Therefore, the force measurements are registered on a computer with the sampling frequency of 20÷50 Hz. This range of sampling frequency and the assurance of a continuous contact of the arm on which the force acts with the force sensor, provides an accurate registration of the rotation resistance.

A force sensor, Z6FC3, accuracy class 0.05%, produced by HBM was used for the testing. Temperature measurements are made using a FLUKE pyrometer 572.

5. TESTS RESULTS

Preliminary tests of the durability of idlers for belt conveyors on the basis of the developed methodology were carried out with regard to smooth idlers with shell diameter of ϕ133 and ϕ159 mm. Both idlers were subject to durability tests, for a total time of 112 hours, according to points A, B, C of the methodology and subsequently the idlers were subject to the final test of dynamic rotation resistance together with temperature measurement of bearing assemblies according to points D and E. The results of the tests are presented in figures 5.1 and 5.2 in the form of graphic charts.

5.1. Test of a smooth idler, ϕ133 mm

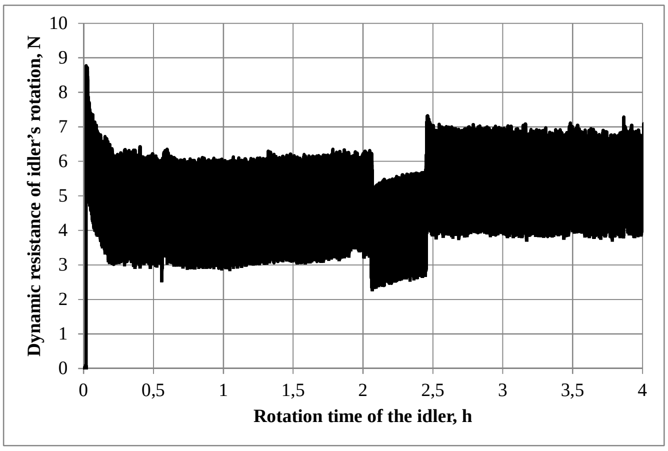

Fig. 8. Test of dynamic resistance of rotation of the idler ϕ133 at a rotational speed of 600 rpm for 4 h

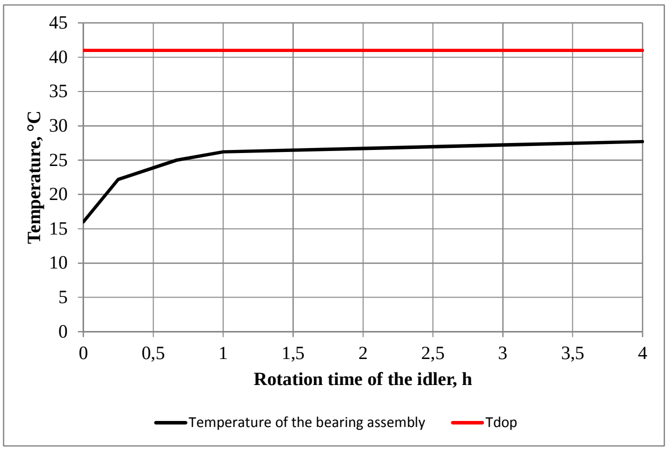

Fig. 9. Test of the temperature of the bearing assembly during the test of dynamic resistance of rotation of the idler ϕ133 at a rotational speed of 600 rpm for 4 bh; T_{dop} – allowable temperature, °C

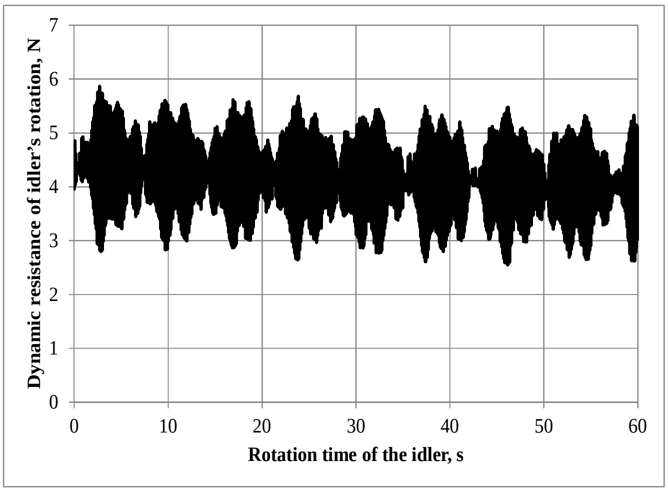

Fig. 10. Test of dynamic resistance of rotation of the idler ϕ133 at a rotational speed of 600 rpm after 4 h of rotation

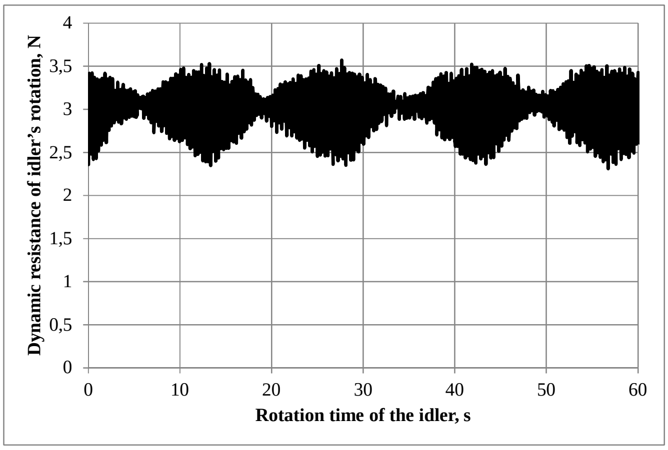

Fig. 11. Test of dynamic resistance of rotation of the idler ϕ133 at a rotational speed of 215 rpm after 4 h of rotation

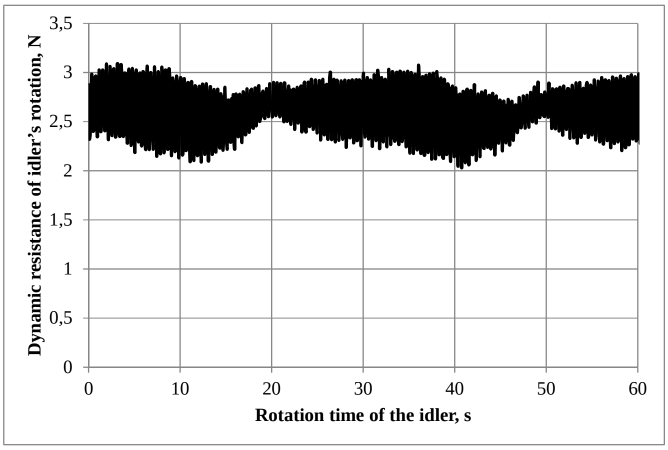

Fig. 12. Test of dynamic resistance of rotation of the idler ϕ133 at a rotational speed of 150 rpm after 4 h of rotation

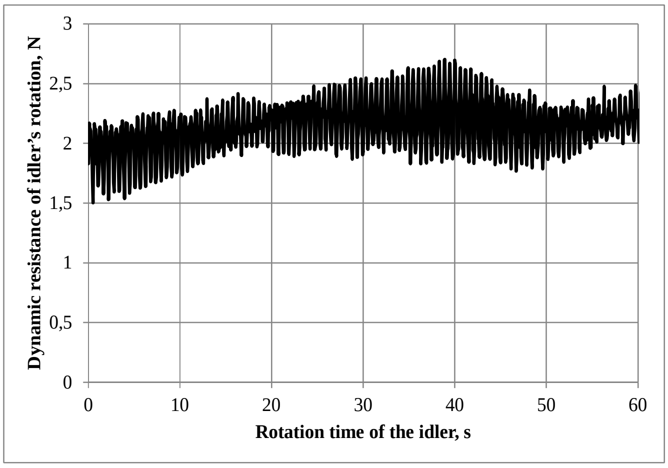

Fig. 13. Test of dynamic resistance of rotation of the idler ϕ133 at a rotational speed of 105 rpm after 4 h of rotation

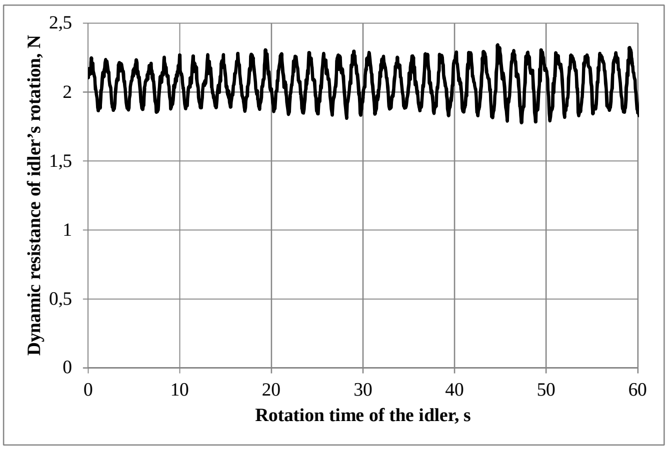

Fig. 14. Test of dynamic resistance of rotation of the idler ϕ133 at a rotational speed of 38 rpm after 4 h of rotation

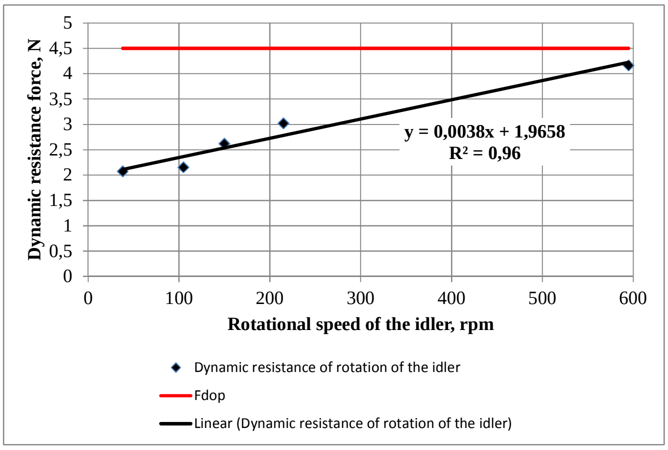

Fig. 15. A graphic chart showing the dependence of dynamic resistance force in the rotational speed function of an idler ϕ133 mm; F_{dop} – acceptable dynamic rotation resistance

5.2. Tests of a smooth idler, ϕ159 mm

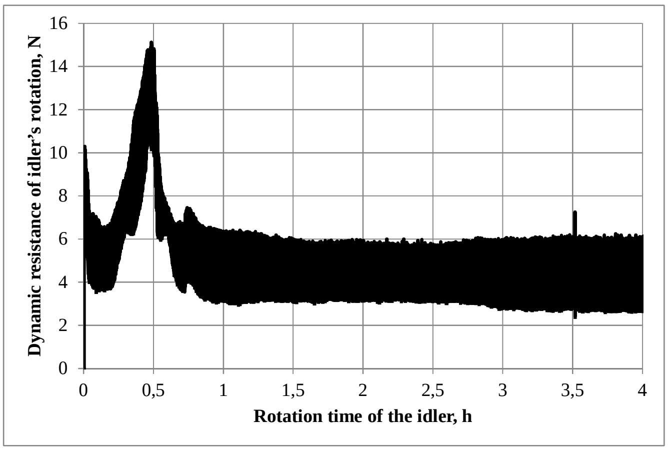

Fig. 16. Test of dynamic resistance of rotation of the idler ϕ159 at a rotational speed of 600 rpm for 4 h

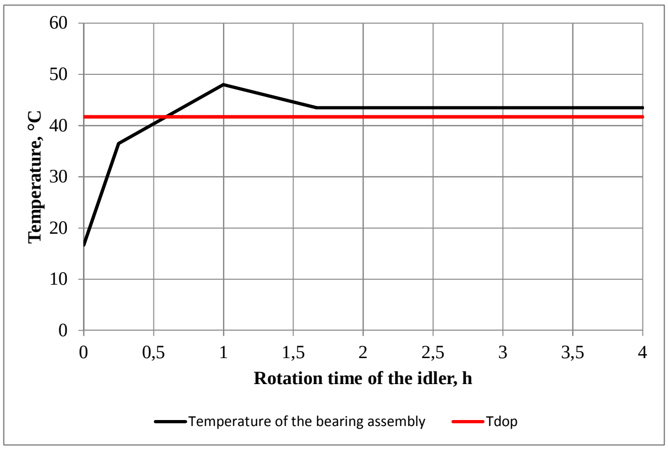

Fig. 17. Test of the temperature of the bearing assembly during the test of dynamic resistance of rotation of the idler ϕ159 at a rotational speed of 600 rpm for 4 h; T_{dop} – allowable temperature, °C

Temperature was measured after 15 minutes, 1 hour, 40 minutes, 2 hours, 3 hours, and 4 hours.

As temperature measurements during the first hour were rare, maximum temperature of the bearing assembly was not recorded during that time.

It is shown on the chart of the registered force of dynamic rotation resistance. In order to avoid such situations in the future, a pyrometer with a continuous measurement of the temperature of the bearing assembly and computer registration within the intervals, the same as the measurement of the force of dynamic rotation resistance, was used.

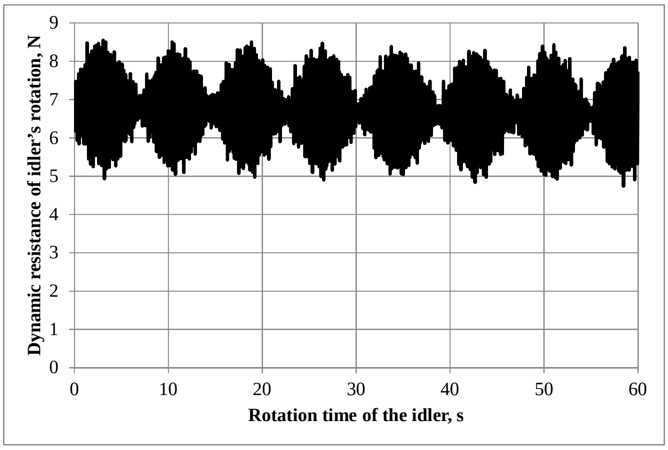

Fig. 18. Test of dynamic resistance of rotation of the idler ϕ159 at a rotational speed of 600 rpm after 4 h of rotation

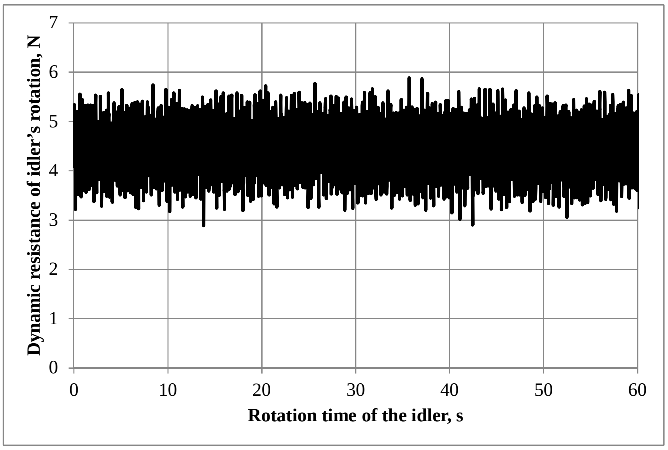

Fig. 19. Test of dynamic resistance of rotation of the idler ϕ159 at a rotational speed of 215 rpm after 4 h of rotation

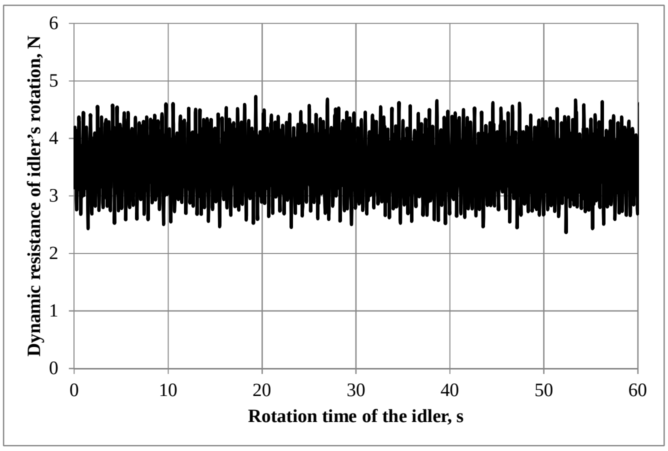

Fig. 20. Test of dynamic resistance of rotation of the idler ϕ159 at a rotational speed of 150 rpm after 4 h of rotation

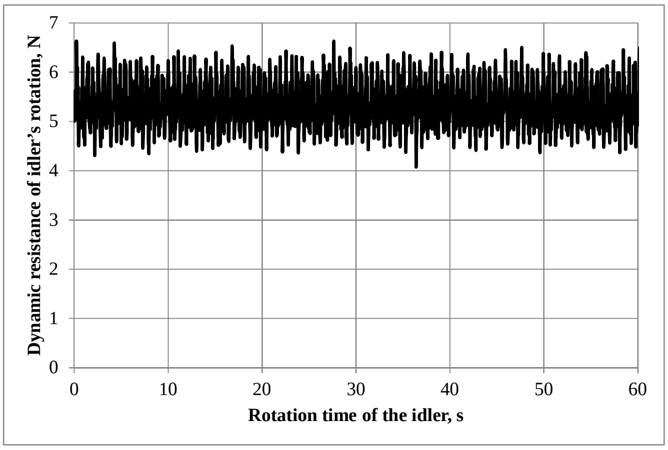

Fig. 21. Test of dynamic resistance of rotation of the idler ϕ159 at a rotational speed of 105 rpm after 4 h of rotation

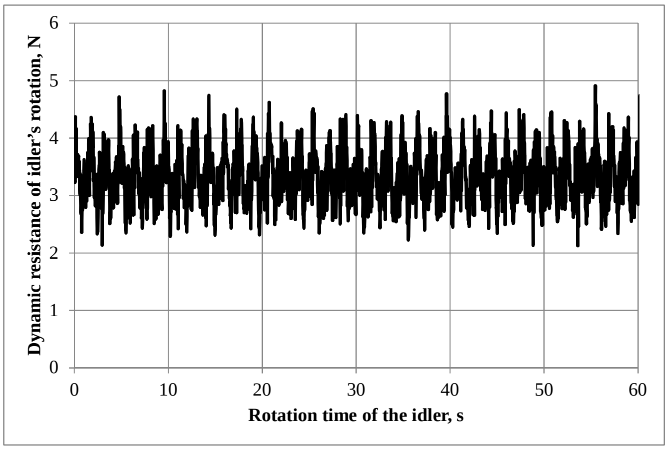

Fig. 22. Test of dynamic resistance of rotation of the idler ϕ159 at a rotational speed of 38 rpm after 4 h of rotation

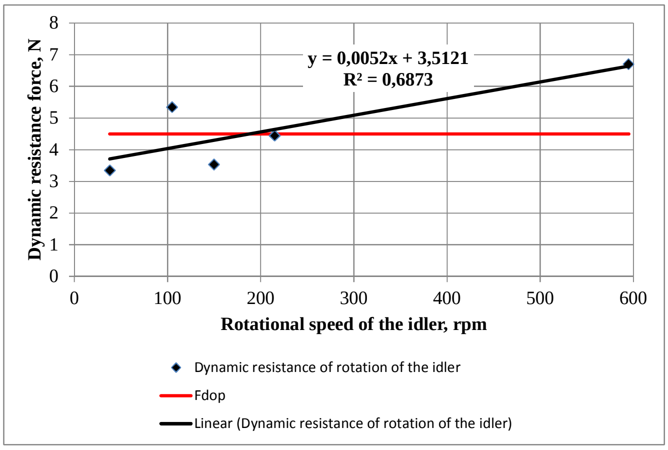

Fig. 23. Dependence of dynamic resistance force in the rotational speed function of an idler ϕ159 mm; F_{dop} – acceptable dynamic rotation resistance

6. SUMMARY

On the basis of the durability tests of the idlers of ϕ133 mm and ϕ159 mm it can be concluded that the applied research methodology describes the test conditions of idlers, in a manner as close as possible to their actual operational conditions, which are subject to a variety of factors for the total time of 116 hours: dust, water, load and variable rotational speed. This methodology allowed us to determine, even at the stage of laboratory tests, the suitability of a particular idler to certain operational conditions.

The durability tests described here show that the idler of ϕ133 mm meets the assumed requirements regarding the temperature of bearing assemblies and dynamic rotation resistance. This idler passed all test stages and new bearing seals developed by the Central Mining Institute and registered in the Patent Office of the Republic of Poland ensured its water-tightness and dust-tightness. The second tested idler, of ϕ159 mm, did not meet the assumed requirements with regards to the temperature of bearing assemblies, dynamic rotation resistance and water-tightness.

The developed methodology for testing idlers has been accredited by the PCA (Polish Centre for Accreditation) with regards to the determination of radial run-out as well as the static and dynamic resistance of idler rotation. The durability tests of the idlers in a dusty environment, water accumulation or under load significantly extend the possibility to evaluate idlers for belt conveyors and can be helpful for other users and designers.

Acknowledgments
This article is part of an undertaking funded under the statutory activity of the Central Mining Institute in Poland.

References

1. Antoniak J. (2007): Przenośniki taśmowe w górnictwie podziemnym i odkrywkowym (Belt conveyors in underground and opencast mining). Gliwice, Wydaw. Politechniki Śląskiej.
2. Gładysiewicz A., Orzeł P., Noga D. (2012): Obniżenie kosztów eksploatacyjnych przenośnika taśmowego poprzez dobór odpowiednich krążników – na przykładzie doświadczeń Zakładów Górniczych Sobieski i Janina. Transport przemysłowy i maszyny robocze Nr 3(17) (Reduction of operating costs of a belt conveyor by using appropriate idlers – on the example of researches of Zakład Górniczy Sobieski and Zakład Górniczy Janina. Industrial transport and heavy machinery No. 3(17). Wrocław, HMR-TRANS Sp. z o.o..
3. Gładysiewicz L. (2003): Przenośniki Taśmowe – Teoria i obliczenia (Belt Conveyors – Theory and calculations). Oficyna Wydawnicza Politechniki Wrocławskiej. Wrocław.
4. Król R., Jurdziak L., Gładysiewicz L. (2008): Gospodarka remontowa krążnikami przenośników taśmowych w oparciu o wyniki badań laboratoryjnych (Maintenance management of idlers for belt conveyors on the basis of the results of laboratory tests). Transport przemysłowy i maszyny robocze Nr 2(2). Publisher: Wrocław, HMR-TRANS Sp. z o.o.
5. Marcinkowski W.A., Kondura C. (2008): Teoria konstrukcji uszczelnień bezstykowych (Theory of construction of non-contact sealing). Kielce, Wydaw. Politechniki Świętokrzyskiej.
6. PN-M-46606:2010 Polish standard – Przenośniki taśmowe – Krążniki (Belt conveyors – Idlers).
7. Pytlik A., Rabsztyn J. (2012): Seal bearing idler belt conveyor. Patent application No. W.121582, UP RP 17.12.2012. Applicant: Główny Instytut Górnictwa, Katowice, Polska.
8. Pytlik A. et al. (2012): Durability testing of idlers for belt conveyors. Documentation No. 11230112-180. Katowice, Główny Instytut Górnictwa. (not published).
9. Riley I.R. (1994): Infra-red condition monitoring application. Proceeding of an International Conference on Condition Monitoring. University College of Swansea, UK 1994.