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A DEVICE FOR MEASURING CONVEYOR BELT THICKNESS AND FOR EVALUATING THE CHANGES IN BELT TRANSVERSE AND LONGITUDINAL PROFILE

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Abstract

Loads acting on the conveyor belt cause it to undergo a continuous process of wear and tear. One of many symptoms indicating such wear and tear is the abrasion of the carrying cover and the pulley cover. Decrements in the belt's cross-section reduce its puncture resistance, thus increasing the risk of core damage. Early detection of even the slightest damage to belt covers and the evaluation of damage increment may help the user to prepare a more precise schedule of current repairs. Such precision will in turn help to minimize losses due to belt conveyor emergency downtime. This article presents a device for measuring conveyor belt thickness and for evaluating the changes in the belt's transverse and longitudinal profile. The measurements are performed continuously, along the belt axis. Belt thickness is measured on a flat section, during belt operation. The device may be applied to any type of belt used in mining industry. The measurement device is managed by an application called DiagBeltSonic, specially designed for this purpose. The application allows the user to define some basic information about the conveyor prior to the test. The measurement results show a sectional view of the belt along the length of the complete loop and also show the longitudinal and transverse profile of the tested belt.

Keywords: belt wear, belt degradation, belt durability

URZĄDZENIE DO POMIARU GRUBOŚCI ORAZ OCENY ZMIAN PROFILU POPRZECZNEGO I WZDŁUŻNEGO TAŚMY PRZENOŚNIKOWEJ

Abstract

Na skutek obciążeń działających na taśmę przenośnikową, ulega ona ciągłemu procesowi zużycia. Jedną spośród wielu oznak jej eksploatacji jest ścieranie okładki nośnej i bieżnej. Ubytki w przekroju poprzecznym taśmy zmniejszają ich wytrzymałość na przebicie co wpływa za zwiększenie ryzyka uszkodzenia rdzenia. Wczesne wykrycie najmniejszych uszkodzeń okładek oraz ocena ich narastania pozwoli użytkownikowi, dokładniej niż dotychczas, planować bieżące naprawy. To z kolei przełoży się w przyszłości na zminimalizowanie strat spowodowanych przerwami w pracy przenośnika taśmowego. W artykule przedstawiono autorskie urządzenie do pomiaru grubości oraz oceny zmian profilu poprzecznego i wzdłużnego taśmy przenośnikowej. Pomiar realizowany jest w sposób ciągły wzdłuż osi taśmy. Grubość taśmy mierzona jest na płaskim odcinku w trakcie pracy przenośnika. Rozwiązanie może być stosowane na każdym typie taśm stosowanych w górnictwie. Do obsługi urządzenia pomiarowego stworzono aplikację o nazwie DiagBeltSonic. Pozwala ona użytkownikowi na wprowadzenie podstawowych informacji dotyczących przenośnika przed rozpoczęciem pomiaru. Wyniki pomiaru przedstawiają przekrój taśmy na całej długości pętli oraz ukazują profil wzdłużny i poprzeczny badanej taśmy.

Key words: zużycie taśmy przenośnikowej, degradacja taśmy przenośnikowej, trwałość taśm przenośnikowych

1. INTRODUCTION

Belt conveyors are the main transportation system used in open cast and underground mining in Poland. Transportation costs are among the most significant costs related to the extraction of minerals, and conveyor belts are the most expensive parts of belt conveyors, both at the initial investment stage and during operation (about 40%, share in these costs [1]). An unplanned downtime of a conveyor route entails significant financial losses. In order to avoid the costly production losses due to emergency downtime [2], belts are given special attention, which in turn increases the cost of labor. Lowering these costs is possible by automating belt condition inspections, monitoring threats including longitudinal cuts, splice breaks and belt breaks, friction between the belt and the conveyor structure, or abrasion of covers, and by generating alarm signals when such threats occur.

The process of the belt's wear and tear is influenced by a number of factors, which may be classified into those related to:
- belt quality: type, design/structure, proper choice of belt to meet the conditions,
- conveyor parameters: length, belt speed, drive type and belt initial tension, cleaning/scraping and guiding/training devices, idler sets [3,10], type of transported material,
- parameters of bulk material: size composition, size and variability of the discharge stream, sharp edges of the particles, viscosity,
- operating conditions: temperature, humidity, sun exposure,
- conveyor service quality: inspection intervals, reaction time to events (e.g. replacement of blocked idlers, or cleaning/scraping devices), repair scope and frequency, observing proper maintenance and operation rules. Many of these parameters are random (load, discharge stream, quality of belt, conveyor configuration, device setup, service quality etc.), and hence the rate of wear and damage is individual and does not lend itself easily to statistical description, while it is the statistical relationship which serves as the basis for determining the optimal belt replacement times in preventive replacement strategies [4]. Besides the above-mentioned factors, the abrasion of the carrying cover and the pulley cover poses another problem. Decrements in the belt's cross-section reduce its puncture resistance, thus increasing the risk of core damage. Early detection of even the slightest damage to belt covers and the evaluation of damage increment may help the user to prepare a more precise schedule of current repairs [5]. Such precision will in turn help to minimize losses due to belt conveyor emergency downtime [2, 6-8].

2. THE DESIGN AND COMPONENTS OF THE DIAGBELTSONIC DEVICE

Devices for measuring conveyor belt thickness and for evaluating the changes in belt transverse and longitudinal profile are already a known technology worldwide (e.g. used by the belt service firm CBM [9]). In solutions offered by other authors, the measuring device is mounted to the structure of the belt conveyor [12]. The principal disadvantage of such solutions is that vibrations of the conveyor negatively affect the measurement results. Another important disadvantage is that no regulation is possible for the distance between the measuring bars, and as a result the device must be mounted on the conveyor with great precision. Correcting the position of the measuring bars is also necessary taken the operating conditions, but takes much time. DiagBeltSonic eliminates all the above listed disadvantages.

The method of measuring conveyor belt thickness and evaluating the changes in belt transverse and longitudinal profile was developed at the Machine Systems Division, Wrocław University of Science and Technology. The device, shown in Fig. 1 and in Fig. 2, comprises two measuring bars placed in parallel one above another. The bars comprise ultrasonic sensors. Both bars are positioned on two adjustable racks. The upper measuring bar has a laser distance sensor.

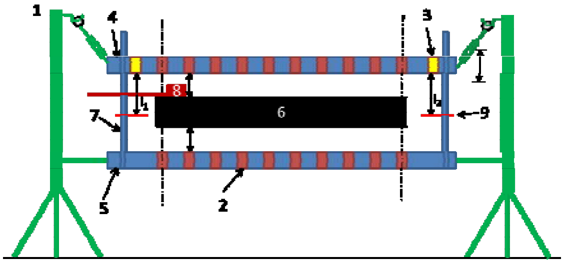

Fig. 1. Diagram of the DiagBeltSonic device: 1 – rack, 2 – ultrasonic sensor, 3 – laser sensor, 4 – movable top metal strip, 5 – bottom metal strip, 6 – belt conveyor, 7 – guide top metal rod, 8 – encoder, 9 – moving calibration plate

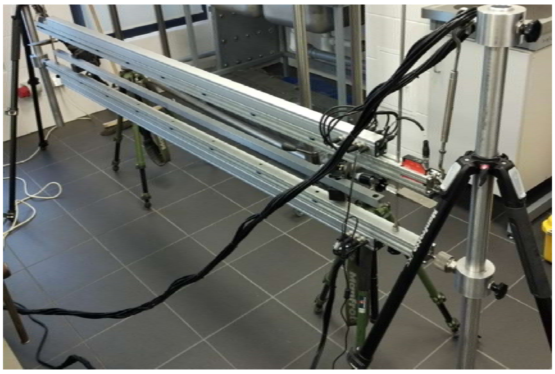

Fig. 2. The DiagBeltSonic device for measuring conveyor belt thickness

The measurement of conveyor belt thickness and the evaluation of the changes in belt transverse and longitudinal profile is achieved by measuring the difference in the distance between the two measuring probes and the tested belt. The parallelism of the two probes (Fig. 3) is determined with the use of two laser sensors positioned on both ends of the measuring bars.

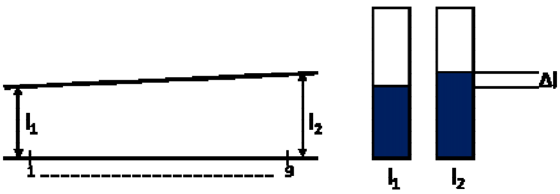

Fig.3. Positioning of the measuring bars with laser sensors

This adjustment is performed before the actual measurement, every time the system is mounted on the belt conveyor. This method allows very precise (down to 0.001 mm) positioning of the probes parallel to each other (Fig. 4).

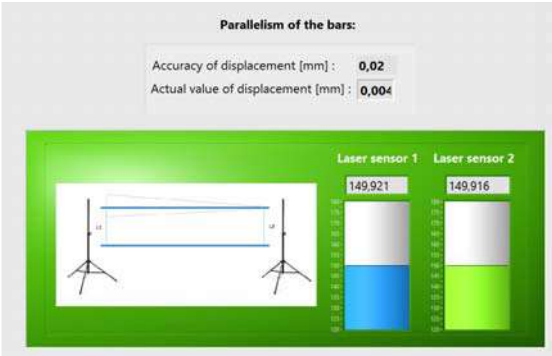

Fig.4. Positioning of the probes before measurements with the DiagBeltSonic application

After this step is complete, the actual measurement can be started. The system automatically switches the ultrasonic sensors on. This method for securing the bars helps ensure that vibrations, impacts of the belt on the measuring probes and the deformations of conveyor structure which occur with time will have no influence on the measurement results. The use of two separate bars facilitates assembly and quick adjustments of the device's position during the measurement. Regulated measuring bars allow the regulation of the device to adjust to the conditions on a given conveyor.

3. RESEARCH WORKS

The device for measuring belt thickness was tested in laboratory conditions on a test conveyor (Fig. 5,6). The test conveyor comprised the same elements as the conveyors operated in mining conditions, i.e. a supporting structure with top and bottom idler sets, drive and tail pulleys and belt tensioning mechanism. Both textile and steel-cord belts can be installed on the test setup. The setup allows developing and testing methods for the evaluation of conveyor belt condition which are based on image analysis and the use of magnetic heads. The speed is regulated in the whole speed range encountered in Polish mining industry, i.e. from 0 m/s to 7.5 m/s.

The test stand was paired with the St 1600 steel-cord belt, 400 mm in width and wrapped around the drive and tail pulleys of 400 mm in diameter. The length of the belting in the loop was 16400 mm. Although the dimensions of the test conveyor do not reflect the dimensions of an actual conveyor, it was possible to recreate some of the actual operating conditions, including:

- measurement at speeds up to 7.5 ms,
- two belt sections in the loop (a used belt with damage typical of actual defects occurring in mining conditions and a new belt without damage).

Tests of the system's effectiveness consisted in multiple measurements of the same belt loop moving with various speeds and in verifying the results. The tests covered the algorithms of the DiagBeltSonic software and its effectiveness in detecting changes in belt thickness.

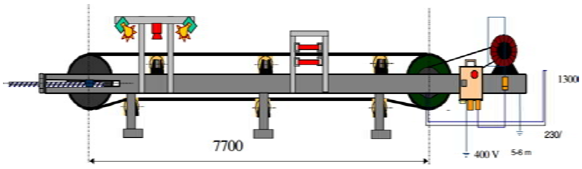

Fig. 5. Test stand for the diagnostics of conveyor belts

The system's software was designed so as to provide the user with control over the correctness and precision of the results at any time. To this end, each test should be preceded by the positioning of the measuring probes in accordance with the procedure described above. Without correct positioning, the software will not allow the user to move to successive steps. In the next stage (the "Configuration" window), the user may enter basic information on the test, the belt, the conveyor and the test parameters.

Fig. 6. General view of the diagnostics of conveyor belts

An important step in the configuration of the system consists in calibrating the ultrasonic sensors. When the device is transported to the measurement site, minor stress may develop in the measuring probes, leading to the maladjustment of the sensors. This step is not required at every successive measurement and the decision is left to the operator, but the function has been introduced to the system in order to reduce uncertainty (Fig. 7).

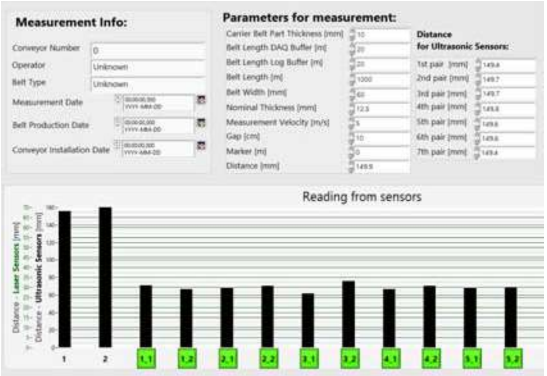

Fig. 7. Basic configuration data and the panel for the calibration of ultrasonic sensors

After it has been properly positioned and calibrated, the system is ready for the proper measurement (the "start" button in the "measurement" window). During the measurement, any characteristic spot on the belt can be indicated by pressing the "marker" button. Such characteristic spots may include damaged edge, or defects of the cover or of the core, etc. After the measurement is complete, a report with test results is generated automatically. The "report" window in Fig. 8 shows a graphic representation of the belt's longitudinal profile.

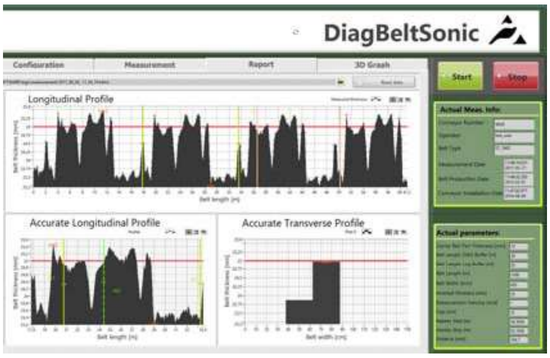

Fig. 8. The "report" window with a preview of measurement results obtained from the test conveyor

During the measurements performed on the test conveyor, the belt loop traveled 4 full cycles, which are shown in in the longitudinal profile. Any fragment of the longitudinal profile can be precisely selected for further analyses (the „accurate longitudinal profile" window). In the case here discussed, one full loop cycle, approx. 16.4 m in length, was selected. The same window allows the user to select (green line) any interesting position on the belt, perform its transverse section and generate a graphic representation of the section in the „accurate transverse profile" window. In addition, graphic 3D representation of the measurement results was introduced (Fig. 9).

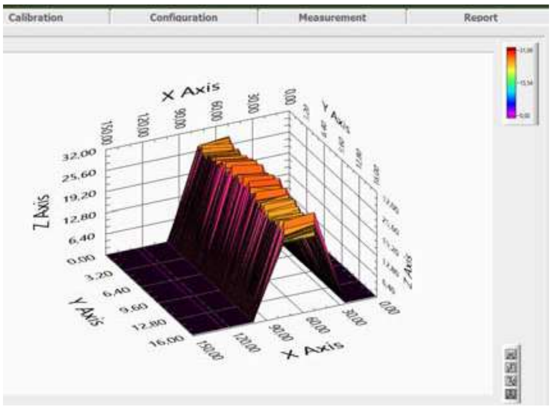

Fig. 9. 3D image of the analyzed belt fragment having width of 400 mm and mean thickness of 24.36 mm.

The graph illustrates only two active (measuring) ultrasonic sensors, since such configuration results from their spacing and from the width of the investigated belt. However, this was enough to test each of the system's functions and prepare it to perform measurements in actual mining conditions.

4. CONCLUSIONS

In Polish mines, measurements of the remaining rubber thickness of in-service belts are done manually in selected points. They are made by pressing the handheld ultrasonic device to cover's surface of the stopped belting during scheduled maintenance breaks in conveyors operations. Lack of representativeness of such results and requirement to make many measurements along the whole length of conveyor in usually harsh environment and hard access to belt surface encouraged the development of a new device. The measurements performed using it on the test conveyor provided highly precise, accurate and repeatable results. The difference in the average thickness of the belt in selected sections and areas as measured in the successive cycles (loops) did not exceed 1%. The system proved to be practical not only because it provided information about the thickness of the belt in any location, or about the belt's longitudinal or transverse profiles, but first and foremost because it provided information about the percentage loss in the cross-sectional area based on 2D wear [11] of the belt as compared to the nominal belt thickness. This information allows the representation of the rate of cover abrasion both in graphical form and as a mathematical. Tests of belt damage indicate that the distribution of defects on the cross-section is not uniform, but concentrates in the central part of the belt [11], in the area affected by bulk material falling on the conveyor at the feeding point. At times core damage on the edges can be identified, which may be the result of the belt's misalignment and the friction between the belt and the conveyor structure. Identifying the actual changes in belt thickness over time may serve to estimate belt replacement times more accurately in order to avoid emergency downtime or to regenerate the belt. Excessive abrasion of the covers together with the core rubber and occasionally even the abrasion of cords disqualifies the belt from regeneration and necessitates the purchase of a new belt. Point measurements of the thickness changes, which are currently performed in mines, do not inform rational decisions, since the values obtained may be random. Knowledge on the changes in the profile of belt thickness may serve to introduce structural modifications (e.g. at the feeding points or at transfer stations), which will lead to more uniform cover abrasive wear.

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