A HIGH RESOLUTION SYSTEM FOR AUTOMATIC DIAGNOSING THE CONDITION OF THE CORE OF CONVEYOR BELTS WITH STEEL CORDS

Ryszard BŁAŻEJ, Agata KIRJANÓW, Tomasz KOZŁOWSKI

Wroclaw University of Technology, Machinery Systems Division
Na Grobli 15, 50-421 Wroclaw, Poland,
e-mail: ryszard.blazej@pwr.edu.pl, agata.kirjanow@pwr.edu.pl, t.kozlowski@pwr.edu.pl

Summary

This paper describes a mobile system for the noninvasive diagnosis of the core of conveyor belts with steel cords. The system is based on the 4-channel magnetic head of the EyeQ system which one of the Polish opencast mines bought at the beginning of the 21st century. Because of the restructuring of the mine and the aging of the EyeQ system, measures were taken to improve the latter's resolution and performance. The upgrading consisted mainly in developing a new software for data analysis automation and in replacing the old hardware platform with a new one increasing six-fold system resulution. The system has successfully passed tests in mine conditions and is currently used to assess the condition of belts working in the mine transport system (fig. 1)

Key words: conveyor belt, non-destructive testing (NDT), diagnosis, belt damage, magnetic method of automatic detection, vision module

SYSTEM WYSOKIEJ ROZDZIELCZOŚCI DO AUTOMATYCZNEJ DIAGNOSTYKI STANU TECHNICZNEGO RDZENIA TAŚM PRZENOŚNIKOWYCH Z LINKAMI STALOWYMI

Streszczenie

W pracy przedstawiono opis mobilnego systemu do bezinwazyjnej diagnostyki rdzenia taśm przenośnikowych z linkami stalowymi. System ten został stworzony w oparciu o 4 kanałową głowicę magnetyczną systemu EyeQ, który na początku XXI wieku zakupiła jedna z polskich kopalni odkrywkowych. Restrukturyzacja kopalni oraz starzejący się, mało wydajny system EyeQ wymusiły działania zmierzające do poprawy rozdzielczości oraz skuteczności jego działania. Głównym celem modernizacji systemu było opracowanie nowego oprogramowania umożliwiającego automatyzację procesu analizy danych oraz zmiana platformy sprzętowej zwiększającej 6-krotnie rozdzielczość systemu. Opisany w pracy system został pomyślnie przetestowany w warunkach kopalnianych i jest obecnie wykorzystywany do oceny stanu technicznego taśm pracujących w systemie transportowym kopalni (rys. 1).

Słowa kluczowe: taśmy przenośnikowe, metody nieinwazyjne (NDT), diagnostyka, uszkodzenie taśmy, automatyczna detekcja metodą magnetyczną, moduł wizyjny

1. INTRODUCTION

In opencast mines transport by belt conveyors equipped with steel cord belts constitutes the main system of hauling the output to a power plant or the overlay to dumping grounds. The efficiency and reliability of the whole transport line to a large extent depend on the condition of the system components. The surface and the core of the conveyor belt – the main system component – are exposed to continual damage. Small damage to the bearing covers and the edges does not pose a direct standstill hazard and is considered to be part of the natural wear of the belt. Whereas point damage and linear damage (longitudinal cuts and slits) to the covers and to the core have a decisive effect on the life of the belt and its ability to carry longitudinal and transverse loads [2]. Detailed information about the number and quality of instances of damage to the belt core, supplied by the diagnostic system enables the users to reliably assess the condition of the belt and to take the correct decision about its further fate.

The EyeQ system was upgraded in two stages. In the first stage, the components of the measuring-analyzing system were replaced and in the second stage, an algorithm for the automatic analysis of the data obtained from measurements was developed [3,4,5].

Fig.1. System during measurements in opencast mine

2. NEW HARDWARE PLATFORM

The principle of operation of the system consists in measuring changes in the magnetic field in the area of damaged conveyor belt core cords. The amplitude of the changes depends on the size and type of damage. The EyeQ system used to offer 4 measuring channels whereby it supplied the user with information from a 60 cm wide belt segment per channel.

The upgrade resulted in a sixfold increase in system resolution, i.e. from 4 to 24 channels, and so a new multichannel data logger had to be employed. For this purpose an 8-slot CompactDAQ chassis (fig. 2) with Ni WLS 9215 modules was used. If one of the channels fails, the cost of replacing the unified four-channel card is not high and the card can be replaced relatively quickly [6]. A module can be replaced by the user without calling service.

Fig. 2. 8-slot Compact DAQ chassis with NI WLS 9215 modules

All the pieces of equipment making up the measuring system have been placed in a Peli box (fig. 3) resistant to the action of noxious and aggressive agents. The box facilitates transport and protects the system components against damage during transport and measurements. The box is equipped with outer interfaces for quick and safe setup of the measuring system devices.

Fig. 3. View of open measuring system box with visible tablet and wiring and during its operation at belt conveyor

3. DESCRIPTION OF SYSTEM FUNCTIONS

The main program window (fig. 4) has been designed having utmost simplicity and clarity of displayed information in mind.

In its top part it shows data on the measurements performed, presenting them in the alphabetical order so as to highlight the most important information about a measurement on a particular belt conveyor. The data can be saved, read in or exported.

The middle part of the window shows a conveyor belt visualization with vertical lines marking the successive belt segments between splices. The system distinguishes 4 alarm thresholds whose limit values are set by the user on the basis of his/her experience and the operational specification of a given belt conveyor.

The colours from green through yellow and orange to red represent damage intensity per 1 running meter of the belt.

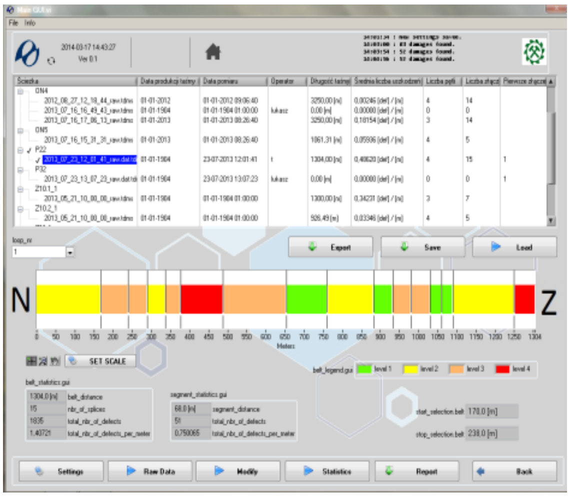

Fig. 4. Main program window with visualization of results after signal analysis

The bottom part of the window shows brief statistics on the number of damage instances on the entire belt and on its selected segment. Also data about the length of the investigated belt and belt segment and the number of detected splices are shown.

3.1. Signal analysis module

The signal analysis module is used:

- during signal acquisition for real time detection of the presence of magnets in order to automatically determine the beginning and end of the belt to be subjected to further analysis, and to determine the number of full loops measured (fig.5);
- after measurement to carry out a post-processing procedure consisting in detecting splices and damage in the successive loops measured.

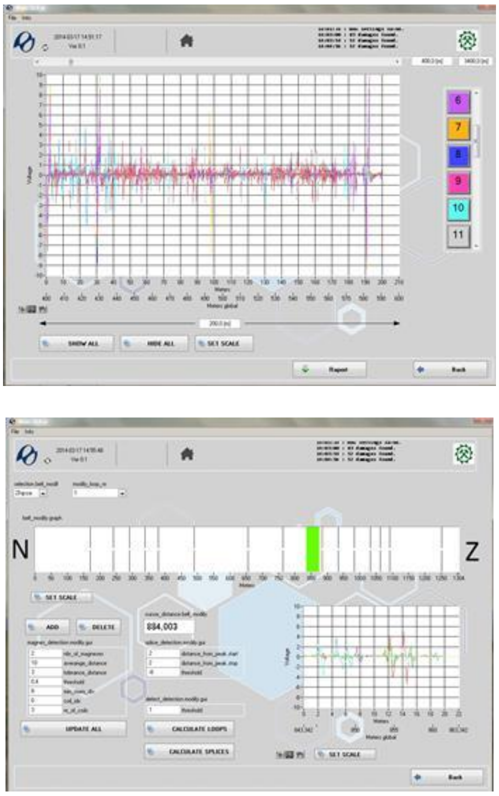

Fig. 5. RAW data analysis and loop and splice detection windows

3.2. Statistical analysis module

Damage (along the cross section) for the 24 measuring channels is presented in two ways: (1) as the number of damage instances (the total number of damage instances for a given channel for the whole belt, for a selected belt segment or its fragment) and (2) as the frequency of damage (the number of damage instances for a given channel, divided by the total number of damage instances, expressed in per cent).

The whole belt or its part, such as a loop, a segment or a segement fragment, is presented as a damage matrix with two (vertical and horizontal) histograms illustrating damage distribution along the belt width and length. The matrix meshes contain the number of damage instances per a unit area (1 measuring channel/1 running meter of belt) (fig. 6), and the colour representing damage intensity.

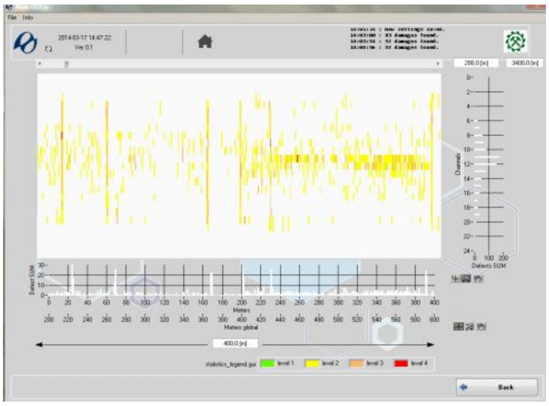

Fig. 6. Statistical analysis window with damage matrix and vertical and horizontal histograms

Using the length and size selection windows the user chooses the size of the belt fragment to be analyzed. Thanks to this way of presenting the results the user instantaneously gets information on the size of the damage instances and their distribution on the whole loop of the analyzed belt.

3.3. Reporting module

The user in a quick and easy way can print out a report on the investigated belt or save it as a pdf file (fig. 7). The content of the report has been consulted with the mine conveyor belt department in order to avoid providing unnecessary information while focusing on supplying the most important data helpful in drawing up plans for belt purchases or belt regeneration and repairs.

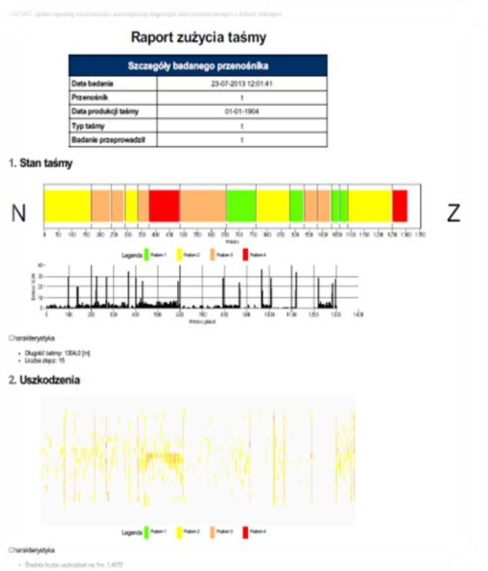

Fig. 7. Report showing belt condition visualization and damage histograms

4. VISION MODULE

Owing to the increased resolution of the system for the magnetic diagnosis of conveyor belts with steel cords any damage can be identified more accurately and its location can be determined more precisely. However, the magnetic signal reading for damage to the steel cords does not provide information about the condition of the load-bearing cover in the place of the damage. For this reason a method of visually assessing belt condition (fig. 8) has been developed in the Department of Machine Systems, Institute of Mining, Wrocław University of Technology [7]. The method consists in the continuous inspection of the conveyor belt by a linear DALSA camera equipped with IMAQ vision software, operating in the LabView environment and in the real-time acquisition of data from this camera. This method makes it possible to detect damage of any type (tears, worn out places, slits, cracks, grooves, delamination, etc.) along the whole width of the belt.

a)

b)

Fig. 8 Visual module during measurements on conveyor: a) view of LED illuminator, b) screen protecting against weather conditions

Initially, the maximum width inspected by the linear Dalsa camera (1) (fig. 8a) amounted to 40 cm whereby no conveyor belts used in the mining industry could be used. Therefore it was necessary to extend the camera's functionality. Work on the software resulted in wider functionality of the camera and currently it is possible to inspect belts up to 3 m wide and running with a speed of up to 7 m/s [7].

In order to obtain accurate results one must ensure optimum operating conditions for the camera. For this purpose the place of measurement is insulated from weather conditions with a screen (fig. 8b) and the belt is uniformly illuminated by a strip of LED diodes (2) (fig. 8a).

The belt is marked on a splice with a marker pen whereby the belt loop can be recognized by the vision system. The data from the camera and from the encoder (3) (fig. 8a) are transmitted in real time to the computer (4) (fig. 8a) and processed by the software which owing to its advanced binary image analysis and filtration functions makes the automatic identification of damage possible [7].

5. SYNCHRONIZATION OF VISION WITH MAGNETIC MODEL

The knowledge relating to damage to the steel cords can be extended to include the type and size of cover damage by using the camera image. For this purpose the two modules were synchronized (fig. 9 for damage and fig. 10 for the splice) to a obtain a 2D image of the belt. Thanks to the early detection of damage the latter can be constantly monitored and decisions as to when the belt should be regenerated or replaced can be promptly made. This is of major importance for the economics of belt conveyor operation since it helps to plan down times and so to minimize financial losses caused by unforeseen stoppages in the haulage of the mine output.

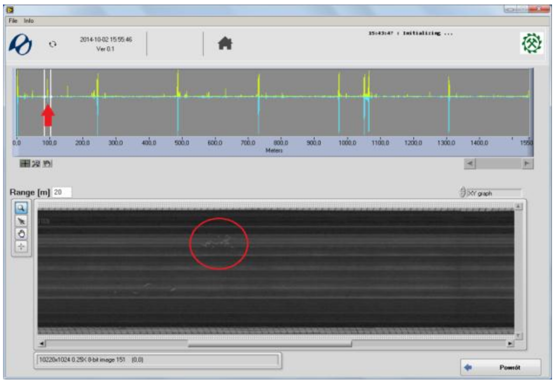

Fig. 9. Synchronized measurement results for vision module (bottom) and magnetic module (top) for belt core and cover (red)

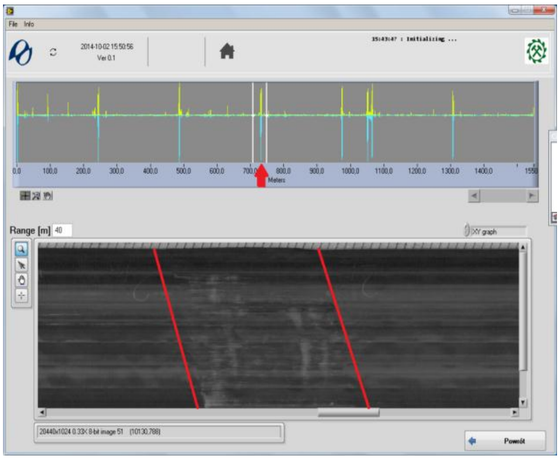

Fig. 10. Synchronized measurement results for vision module (bottom) and magnetic module (top) for belt splice (red)

Figure 9 shows damage detected on the inspected conveyor belt. The program enables one to easily determine the distance of the damage from the beginning of the loop. In the magnetic diagram this damage is visible as a stronger signal resulting from a change in the induced magnetic field (above the red arrow). For a given range (here 20 m) it is possible to display the image from the vision system whereby the damage to the cover (red circle), resulting from damage to the core, can be located.

Similarly is in the case of the signal for a vulcanized belt splice shown in figure 10. Magnetic signals for splices are much stronger and so easy to identify in the diagram. There are 8 splices in the considered belt. For a given range (here 40 m) it is possible to find the splice in the vision module (red lines) and to assess the condition of the cover in this place.

6. CONCLUSION

Thanks to the new version of the automatic diagnostic system the measuring process and the analysis of the signals after the measurement have been automated. Such functions as the automatic start, the detection of the number of complete belt conveyor loops, the automatic measurement and automatic detection of damage were not available in the previous version of this measuring system.

The open character of the system, mainly of its software, made it possible to develop automatic procedures for data processing and analysis, reporting, real-time monitoring and statistical analyses.

The software already at the measuring stage enables the user to analyze the condition of the belt on the conveyor and to precisely locate, classify and quantitatively assess belt damage.

The new hardware platform ensures the maintenance-free use of the system and if a failure occurs, it can be quickly removed through the replacement of the unified measuring modules without it being necessary to call specialized service.

Owing to the synchronization of the images obtained by two methods, i.e. the magnetic method and the vision method, the degree of damage to the belt can be more precisely determined whereby conveyor downtimes can be planned in advance, minimizing the risk of a breakdown and so reducing potential financial losses.

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REFERENCES

[1] Błażej R., Jurdziak L., Zimroz R.: *Need for developing in-house diagnostic equipment for automatic assessment of condition of conveyor belts in opencast mines* (in Polish). Górnictwo i Geoinżynieria. 2011, R. 35, no. 3/1, pp. 63-71.

[2] Żur T., Hardygóra M. *Belt conveyors in mining* (in Polish). 1996.

[3] Błażej R., Jurdziak L.: *Integrated diagnostic device for automatic assessment of conveyor belts condition*. In: 22nd World Mining Congress & Expo, 11-16 September, Istanbul-2011. Vol. 3 / ed. Şinasi Eskikaya. Ankara : Aydoğdu Ofset, cop. 2011. pp. 675-680

[4] Zimroz R., Makowski R., Błażej R.: *A method of damage detection in conveyor belts with steel cords by NDT signal processing*. Proceedings of The Eighth International Conference on Condition Monitoring and Machinery Failure Prevention Technologies, CM2011/MFPT2011 Cardiff, Wales, (20-22 June 2011), Coxmoor Publishing Company Zimroz Makowski.

[5] Błażej R., Jurdziak L., Zimroz R.: *Novel approaches for processing of multi-channels NDT signals for damage detection in conveyor belts with steel cords* / R. Blazej, L. Jurdziak and R. Zimroz [i in.]. Key Engineering Materials. 2013, vol. 569/570, s. 978-985

[6] Błażej R., Zimroz R., Nowak R., Grzyb K., Kurp Ł.: *Extension of EyeQ system functionality to cover diagnostics of core of ST belts* (in Polish). Transport Przemysłowy i Maszyny Robocze. 2010, no. 3, pp. 24-28.

[7] Błażej R., Hardygóra M., Jurdziak L.: *Optical device for visual assessment of the surface condition of conveyor belts* (in Polish). II International Congress of Copper Ore Mining [Electronic document]: *Perspectives and trends of development*: Conference materials, Lubin, 16-18 July 2012. Wrocław : KGHM CUPRUM, [2012], s. 244-253