Mining Science, vol. 23, 2016, 173−182

www.miningscience.pwr.edu.pl

Mining Science
(previously Prace Naukowe Instytutu Gornictwa Politechniki Wroclawskiej, ISSN 0370-0798 in Polish)

ISSN 2300-9586
previously 0370-0798

Received: June 5, 2016; reviewed; accepted September 11, 2016

A NEW TOOL IN BELTS RESISTANCE TO PUNCTURE RESEARCH

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Abstract: In the Belt Conveying Laboratory (LTT) at the Faculty of Geoengineering, Mining and Geology at Wroclaw University of Technology a new area of application has been found for the newly developed high resolution magnetic diagnostic device for assessment of steel cord conveyor belts condition. In addition to monitoring of belts during their operation on conveyors this device can be used in LTT as the new tool in belts resistance to puncture investigations. High resolution images of changes in magnetic field of magnetized cord wires can be used for evaluation of failures and cuts caused by dynamic impact of iron head (striker) during laboratory tests without belt cover removal. The usefulness of the device is even greater due to not only condition of steel cord belts can be evaluated, what for this device was developed, but it allows also on observations of failures in impact-resistant metal breakers in textile belts. Breakers are frequently made of thin wires vulcanized above carcass inside the top cover laterally to the center line of the belt. The aim of breakers is protection of the expensive core against failures caused by big lumps of rock with sharp edges falling onto belt surface in loading points. Their role is shock absorption to minimize gouging and resistance of longitudinal rips. Due to breaker wires can also be magnetized after changing the direction of samples of punctured belts they can be monitored using the developed device at the testing conveyor. In the paper the first outcomes of application of magnetic diagnostic device for evaluation of punctured steel cord belts and textile belts with metal breakers are presented.

Keywords: conveyor belt condition, condition monitoring, belt failures

RESEARCH INTO INTEGRATED DIAGNOSTIC SYSTEM AT MACHINERY SYSTEMS DIVISION (MSD)

As a part of NCBiR project (Applied Research Program 1, Path A) entitled: “An intelligent system for the automatic examination and continuous diagnosis of the condition of conveyor belts,” Machinery Systems Division at the Faculty of Geo-

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doi: 10.5277/msc162314

engineering, Mining and Geology at Wroclaw University of Technology developed an integrated adaptive diagnostic system adjusted to operating conditions for individual conveyors (Blazej et al, 2011–2014).

One of its main modules is a magnetic system for examining the condition of steel-cord belt core. The prototype was based on Belt Guard system from Australian company Beltscan Pty Lt. The final high-resolution measuring bar was equipped with software allowing for data analysis and damage imaging in both 2.5 D mode (Fig. 1), as well as 3D presentations (Fig. 1).

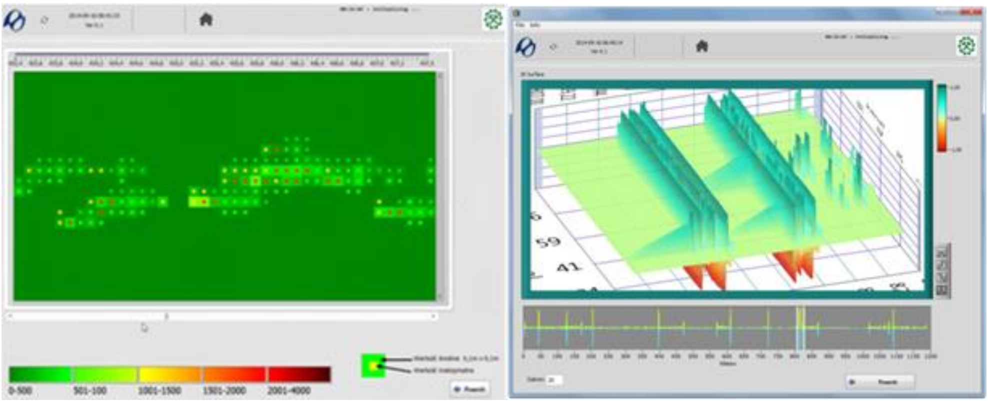

Fig. 1. Belt condition image: 2.5 dimensional – color represents average value of raw signal in area 10 × 10 cm with dot in the center showing its maximal value (left panel) + 3 dimensional – 3 D image of a wave signals (positive – green and negative – red) (right panel)

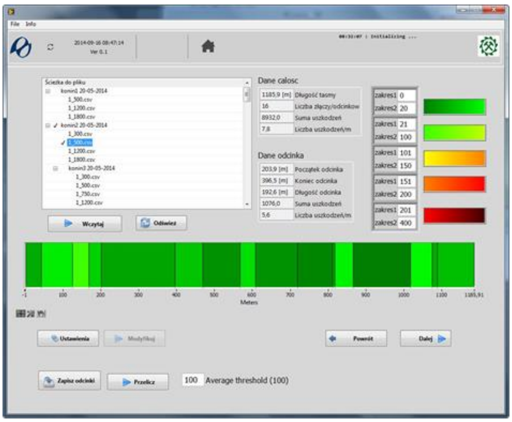

Fig. 2. Main image of magnetic module of the integrated diagnostic system showing structure of data file (upper left), information about belt loop (length, number of splices, number of failure (upper middle) and code of colors (upper right) and the image of open belt loop with particular belt segments – colors show average failures density (bottom)

Users also have the possibility to acquire rapid examination of all belt sections in the loop on the inspected conveyor (Fig. 2), which is done on the basis of aggregated data on damage density (number of events per 1 running meter of belt). Owing to color coding in 5 ranges, this allows for effortless estimation of the condition of all belt sections. The splices are automatically identified and saved separately for subsequent visual inspection. Plans for the future include automatic evaluation of splice quality and its condition, by comparison with the model splice. Predicting module (Blazej et al, 2014) allows to establish individual damage growth trajectory on the basis of the recorded pace of new damage growth between consecutive belt inspections, which in turn allows for individual prognostics of the remaining operating time for all belt sections in a loop on a conveyor (Fig. 3).

Possibility of observation of steel cord condition changes during operation has created an excellent opportunity to compare not only different belts, but also in the course of damage formation on conveyors working in different conditions (with different length, belt speed, the type of ore, etc). Investigations of belt condition changes in different periods allows for linking the results of belt resistance to puncture with their long service life (Fig. 3), and it is possible to assess whether the belt design modifications as well as transfer points construction changes entailing an increase in the cost will be recouped by reducing emergency stops due to belt failures and extending belts durability, thus reducing costs of their replacements. It should also lead to reliable prediction methods which take into account the influence of differences in belt resistance to punctures on their service life based on the observations of the actual process of their degradation during operation determined by means of an integrated belt diagnostic system.

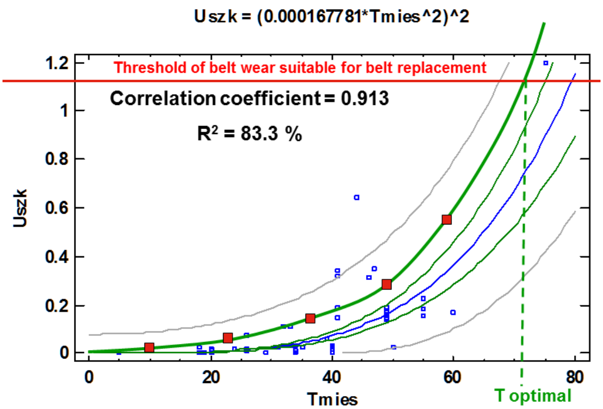

Fig. 3. Belt segment failures density trace (red squares with green line showing rate of density of potential failures increase) on the background of statistical data for different belt segments can be used for selection of optimal belt replacement time which can be found in the crossing point of green line with belt wear threshold (Blazej et al, 2014)

TESTS OF CONVEYOR BELTS PUNCTURE RESISTANCE CARRIED OUT AT BELT CONVEYING LABORATORY (LTT)

Tests of conveyor belts puncture resistance have been carried out at Machinery Systems Division (MSD) at Wroclaw University of Technology since mid-1980s, having begun at approximately the same time as in other research centers worldwide (Ballhaus, 1983). Performed under the supervision of Monika Hardygora, the tests included both textile and steel-cord belts (Hardygora, 1984 a & b). The analysis focused on how feeder parameters and belt support at the material feeding point to the belt influence damage occurrence (Hardygora & Golosinka, 1984). Also investigated was the influence of cord construction and belt parameters on the process of damage creation (Hardygora & Golosinksa, 1986), especially the influence of cover thickness and other events location (Hardygora, 1984a & b).

Presently research into conveyor belts puncture resistance and belt wear process modeling is continued at MSD, at Wroclaw University of Technology (Bajda & Gancarek, 2015; Komander et al, 2014a & b).

Another important center where such research is performed is located at Technical University of Kosice (Fedorko et al, 2013a & b; Grinčová & Marasová, 2014). Unfortunately, due to lack of standards for research into conveyor belts puncture resistance, as well as lack of consistency in approach (diversified test towers, strikers, measurement methods, averaging methods, different types of apparatuses, etc.) the results obtained in various research centers are similar and yet incomparable.

The Belt Conveying Laboratory (LTT) at the Faculty of Geoengineering, Mining and Geology at Wroclaw University of Technology has developed its own methodology of research, because there are no standards governing the manner in which they should be conducted. Consequently, the results from different research centers are not comparable with each other. Despite this, the investigation results of impact influence on belts from different manufacturers and having different construction carried out in the same laboratory are valuable for producers and users, as they allow for better selection of belts to particular harsh working conditions and provide the longest trouble-free operation in such environment. Unfortunately, despite previous attempts at belt-life prediction (Jurdziak, 1990, 1996, 2000) including methods based on the designated boundary energy destroying belt covers and cords, a revised method for determining how differences in belt puncture resistance (Hardygora, 1988) translate into differences in their durability till now have not been developed.

In laboratory conditions, it is possible to prove that a belt from manufacturer A has greater puncture strength than a belt from manufacturer B, or that a reinforced structure belt is much stronger than a belt without reinforcement, or that a new very strong material may replace steel-cord belts as it has not only greater durability but also greater puncture strength. Unfortunately, it is difficult to check how the identified strength differences translate into durability differences in real-operation conditions.

Questions remain whether increased financial spending on reinforced belts could translate into increases in belt life-times long enough to increase the company's profit.

Research done in the 1980s led to developing a simulation model, which allowed to select a belt suited to the predicted operating conditions and to estimate its durability (Hardygora, 1988). Unfortunately, with belt life-time approaching several dozen months, verification of the simulation model based on real-operation data proved very difficult. Such verification has now become possible, due to introduction – both in the mine and at the University – of diagnostic tools measuring scope of damage in steel-cord belt core.

RELATION BETWEEN PUNCTURE RESISTANCE TESTS AND CORE CONDITION ANALYSIS USING MAGNETIC SYSTEMS

Conclusions from the investigations into belts puncture resistance indicate clearly (Ballhaus, 1983; Fedorko et al 2013a & b) that core damage scope and intensity are much greater than size of rubber failures observed on core surface. After the striker hits stretched belt, only a darker spot of friction-heated rubber can be observed on top cover, in the place where the striker's head hit the rubber, as well as a small breakage of ply rubber in the middle of the spot, while under the cover, after its removal, longitudinal rubber breakages may be observed along the cords, accompanied by rubber loosening on a distance much longer than surface damage (Fig. 4).

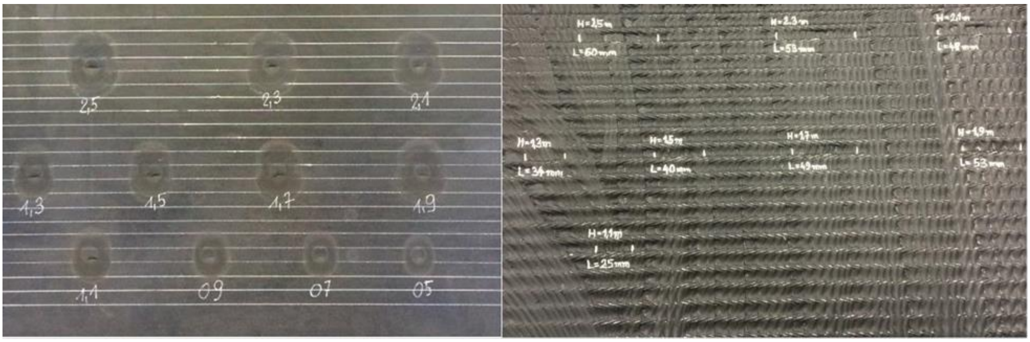

Fig. 4. Damage seen on belt top cover (left panel) vs condition of belt core disclosed after top cover removal (right panel). Visual inspection of the results of tests on steel-cord belts puncture resistance shows greater size of core damage along ropes (right panel) than small cuts in rubber and black fringes around them visible on belt surface (left panel)

In case of steel-cord belts, as the result of the striker puncturing top cover rubber and carcass rubber (it has been practiced to choose impact spots between cords), ply rubber is ripped off the cord on the distance of several centimeters or greater. Damaged area grows linearly together with increasing energy. In case of textile belts, nonlinear growth of damaged area can be observed in relation to the striker's energy, which can be explained by the fact that energy needed to destroy adhesion and break threads in the fabric in all directions must increase to the power of two in order to increase damage by one unit.

Performing research into puncture resistance alongside with magnetic diagnostics of belt core condition will allow to adequately correlate results of puncture resistance tests with core condition. In order to assess cord damage, steel-cord belt puncture resistance tests should be modified to direct striker head's impact not only between the cords but also directly at cords, as it is nowadays possible to use magnetic scanners to estimate the nature and severity of cord damage (Fig. 5).

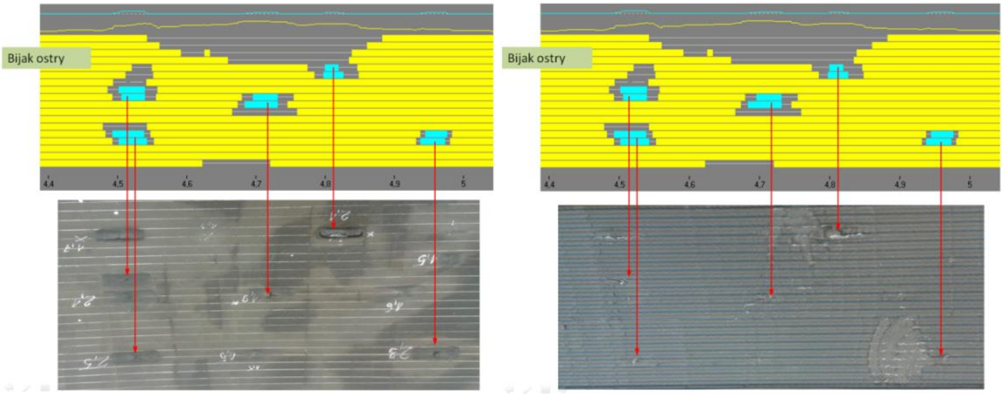

Fig. 5. Damage of belt top cover (bottom panels) vs belt core condition shown with the image from magnetic diagnostic device (upper panels) before (left panel) and after top cover removal (right panel). Yellow and blue colors show changes of magnetic field sign. Length of blue color area is proportional to the cord damage intensity (its size). Arrows link failures seen on belt core image and belt surface picture

It can be seen that the cord failures (wire cuts) depend not only from the height of striker level but also from the central hitting of the cables. Sometimes the striker head hits only one of cord sides and slides over it causing greater rubber failures and sometimes cuts the cord centrally creating big change of response signal due to strong cord damage and only small rubber damage. Different colors (yellow and blue) represent different signs of the magnetic field at selected level of its measurements. The length of blue color area is proportional to the cord damage size and intensity.

Similar images can be generated by scanning of textile belt with wire breakers (Fig.6). It can be seen that damages in the form of breaking the adhesion of rubber to the wire (black lines on yellow core rubber above centimeter ruler, Fig.6 bottom panel) are much greater than small, hardly seen, signs on the black belt cover (Fig. 6, upper panel). It is important to know that wire breakers are placed horizontally (Fig.6) and the next hits were done to the same, already cut wires, what should be avoided in next research. Adhesion of rubber to wire after each hit is already destroyed (in some lengths) so it is more easy to create next failures and result could be misleading. Central strikes of belt cables create greater wire damage what is seen in length of blue signal area than failures in belt cover rubber.

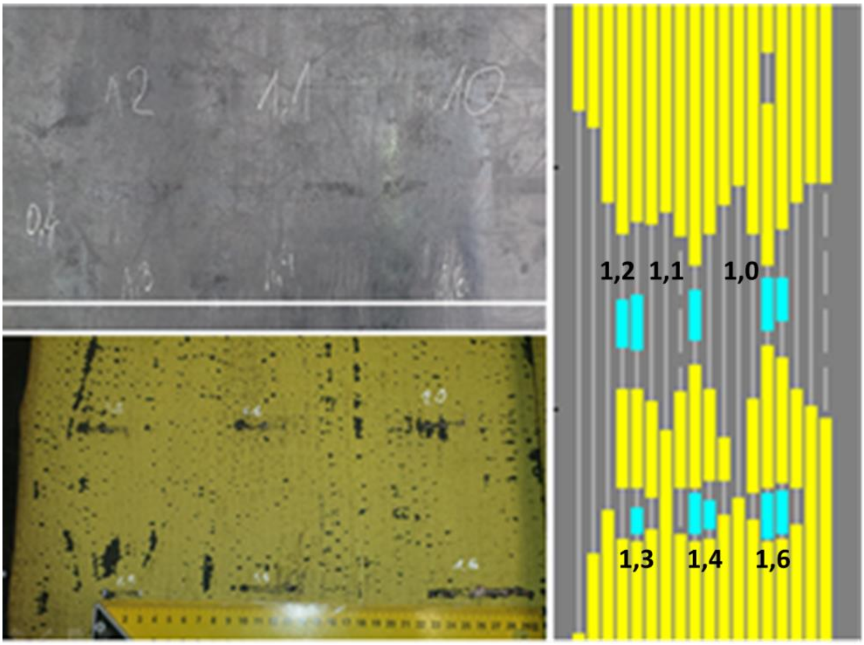

Fig. 6. Damage on belt top cover surface (upper panel) vs yellow belt core condition after belt cover removal (bottom panel) shown together with the image from magnetic diagnostic device (right panel) for textile belts with wire breakers. Numbers represents the height of sharp striker level in meters (Tab.1)

Table 1. Correlation of height of striker levels with number of cut wires and the length of adhesion destruction.

Height of the striker level H m	Number of cut wires	Length of the rubber damage mm
1,0	3,0	30,0
1,1	3,0	32,0
1,2	4,0	33,0
1,3	2,0	30,0
1,4	3,0	34,0
1,6	4,0	50,0

CONCLUSIONS

The paper presents first results of application of magnetic diagnostic device developed in the Belt Conveying Laboratory (LTT) at the Faculty of Geoengineering, Mining and Geology at Wroclaw University of Technology in belts resistance to puncture research. In addition to monitoring of belts during their operation on conveyors this device can be used in LTT as the new, additional tool, for evaluation of condition of steel wires not only in steel cord belts but also in textile belts with wire breakers used to protect the expensive carcass against failures caused by big lumps of rock with sharp edges falling onto belt surface in loading points. Breakers role is shock absorption to minimize gouging and resistance of longitudinal rips so their condition evaluation after hitting the belt by strikers is a valuable addition to visual inspection.

Conducted research proves that extension of a magnetic device application is possible and could help in better research of belt carcass protection.

It was also once again proved (e.g. Hardygora & Pelc, 1981; Fedorko et al, 2013a) that scale (size) of belt core failures is much greater than its image seen on belt cover surface in place of belt puncture (small cuts in rubber and black fringes around them).

The intensity of cord failures depends not only from the height of striker level but also from the place of hitting the cable. Careful selection of place of wire hitting is recommended.

Performing research into puncture resistance alongside with magnetic diagnostics of belt core condition should allow to adequately correlate results of puncture resistance tests with core condition. In order to assess cord damage, steel-cord belt puncture resistance tests should be modified to direct striker head’s impact not only between the cords but also directly at cords, as it is nowadays possible to use magnetic scanners to estimate the nature and severity of cord damage.

In the next research hitting many times the same breaker wire should be avoided due to incomparable results of next strikes, provided that impact of multiple shocks influence will be examined purposely. The first hit destroys the adhesion of the rubber to the core wire and next strikes, even with greater energy, can cause smaller failures (Fig.6 and Table 1).

The research will be continued and soon next, more quantitative than qualitative as here, results will be presented.

ACKNOWLEDGEMENTS

This paper was financially supported by statutory activity, No: S50136

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