The International Journal of
TRANSPORT & LOGISTICS
Međunarodni časopis
TRANSPORT I LOGISTIKA

UDC: 622:67.05:622.647.2

CONVEYOR BELT WITH INCREASED OPERATIONAL WEAR RESISTANCE

TRANSPORTER SA TRAKOM SA POVEĆANIM OTPOROM NA HABANJE U TOKU RADA

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Abstract: *Belt conveyors are the basic haulage facilities in Polish mining industry. Their total length amounts for over 1100 km, it means that more than 2400 km of conveyor belts is in operation. Cost of transport of excavated material in the open pit lignite mines constitutes about 30% of mining costs. Many years of operating tests showed that most of belts is worn and as a consequence dismantled from the conveyor, due to the damage caused by puncture or cut. Thus, it may be assumed that the resistance to puncture and longitudinal cut of conveyor belts are one of the most important criteria in evaluating their operational durability.*

Key words: *mining, belt conveyor, wear resistance.*

Apstrakt: *Transporteri sa trakom su osnovna prevozna sredstva u poljskoj rudarskoj industriji. Njihova ukupna dužina iznosi preko 1100 km, što znači da je u pogonu više od 2400 km transportnih traka. Troškovi transporta otkopanog materijala u površinskim rudnicima lignita čine oko 30% troškova eksploatacije. Dugogodišnja ispitivanja u toku rada pokazala su da se usled pohabanosti većina traka uklanja sa transportera, a uzrok oštećenja su najčešće naprsline ili rupe na gumi. Stoga, može se pretpostaviti da je otpornost na pucanje i uzdužno cepanje transportnih traka jedan od najznačajnijih kriterijuma u ocenjivanju njihove operativne trajnosti.*

Ključne reči: *rudarstvo, transporter sa trakom, otpor na habanje*

1 INTRODUCTION

Belt conveyors are the basic haulage facilities in Polish mining industry. Their total length amounts for over 1100 km, it means that more than 2400 km of conveyor belts is in operation. Cost of transport of excavated material in the open pit lignite mines constitutes about 30% of mining costs. Thus, the mines are vitally interested in seeking the technical solutions aimed to reduce the extraction costs. While running along the conveyors the belts subject the different loads causing the process of their

1 UVOD

Transporteri sa trakom su osnovna prevozna sredstva u poljskoj rudarskoj industriji. Njihova ukupna dužina iznosi preko 1100 km, što znači da je u pogonu više od 2400 km transportnih traka. Troškovi transporta otkopanog materijala u površinskim rudnicima lignita čine oko 30% troškova eksploatacije. Prema tome, rudnici su živo zainteresovani da se pronađu tehnička rešenja koja imaju za cilj da se smanje troškovi otkopavanja. Dok prelaze duž transportera, trake su izložene raznim opterećenjima koja uzrokuju destroying [1]. The procedure of belts wear is a result of belt type, its lengths, type of transported material and place of operation [2]. The evaluation of operational resistance of the conveyor belt in the laboratory needs to define numerous properties such as: tensile and extension (longitudinal and crosswise) strength, delamination and shear strength, tensile strength of rubber lining, and their abrasive and ageing strength, belt resistance to low temperatures, combustibility and others. Methods of determining the above values as well as requirements concerning those properties are standardized. There is still a group of belt properties having critical importance with regard of their operational durability, and which do not have the relevant normative acts yet. Many years of operating tests showed that most of belts is worn and as a consequence dismantled from the conveyor, due to the damage caused by puncture or cut. Thus, it may be assumed that the resistance to puncture and longitudinal cut of conveyor belts are one of the most important criteria in evaluating their operational durability [3].

Operating under the increasing competition pressure and higher customers requirements, producers of conveyor belts are forced to search continuously the new and improved solutions. It is obvious that each new solution must go through the applicable tests, preferably giving the results within relatively short period of time. There is, than, a demand for development and modernization of laboratories as well as research methods, which could quickly and precisely evaluate the quality and expected durability of the product under the given working conditions [4,5]. Belt Transport Laboratory of Mining Institute at Wroclaw University of Technology (LTT) owns the installation unique in Poland, which allows to test the belts resistance to longitudinal cut. Moreover, in 2009 the testing stand used to determine the puncture resistance of belts was commissioned. The device was purchased within the 2009 grant of Ministry of Science and Higher Education. Using those facilities and other devices available in the LTT laboratory, it is possible to develop the conveyor belts with increased resistance to operational wear, designed especially for coal, copper or hard rock mining industry. Different kinds of belt constructions as well as various types of cross reinforcement increasing their cut and puncture resistance will be tested there. The results should help to formulate the guidelines for production of

njihovo propadanje [1]. Habanje traka zavisi od vrste trake, njene dužine, vrste materijala koji se transportuje i mesta rada [2]. Ocena otpora u toku rada transportne trake u laboratoriji treba da definiše brojna svojstva kao što su: čvrstoća na kidanje i istezanje (po dužini i po širini), čvrstoća na delaminaciju (raslojavanje) i statičko naprezanje, otpornost na kidanje gumene obloge, i njihova otpornost na abraziju i starenje, otpornost trake na niske temperature, zapaljivost i drugo. Standardizovane su metode za utvrđivanje gore navedenih vrednosti kao i zahtevi koji se tiču tih osobina. Ipak, postoji grupa osobina trake koje imaju ključni značaj u pogledu njihove operativne trajnosti a za koje još uvek ne postoje odgovarajući propisi. Dugogodišnja ispitivanja u toku rada pokazala su da se usled pohabanosti većina traka uklanja sa transportera, a uzrok oštećenja su najčešće naprsline ili rupe na gumi. Stoga, može se pretpostaviti da je otpornost na pucanje i uzdužno cepanje transportnih traka jedan od najznačajnijih kriterijuma u ocenjivanju njihove operativne trajnosti [3].

Radeći pod sve većim pritiskom konkurencije i zahtevima korisnika, proizvođači transportnih traka su primorani da neprestano tragaju za novim i naprednijim rešenjima. Očigledno je da svako novo rešenje mora proći kroz određene testove, po mogućstvu da daju rezultate u relativnom kratkom vremenskom roku. Zatim, postoji potreba za razvojem i modernizacijom laboratorija kao i metoda istraživanja, koje bi mogle brzo i precizno da procene kvalitet i očekivano trajanje proizvoda u datim radnim uslovima [4,5]. Laboratorija za transport putem traka Rudarskog Instituta Tehnološkog Univerziteta u Vroclavu (LTT) poseduje jedinstveno postrojenje u Poljskoj, koje omogućava da se testira otpornost traka na cepanje po dužini. Štaviše, godine 2009. nabavljen je uređaj za testiranje koji se koristio za određivanje otpornosti traka na cepanje. Uređaj je kupljen zahvaljujući subvenciji iz 2009. godine Ministarstva za nauku i visoko obrazovanje. Pomoću ovih postrojenja i drugih uređaja koji su na raspolaganju laboratoriji na LTT-u, moguće je izraditi transportne trake sa povećanim otporom na habanje pri radu, namenjenih isključivo za industriju eksploatacije uglja, bakra ili čvrstih stena. Tamo će biti testirane različite vrste konstrukcija sa trakom kao i različiti tipovi poprečnih ojačanja koja će povećati njihovu otpornost na cepanje i probijanje. Rezultati bi trebalo da pomognu da se formulišu smernice za belts with higher operational durability, what in turn should widen the offer of the belts being produced, in order to adapt their properties to the specific operational conditions more effectively.

2 TEST OF PUNCTURE RESISTANCE OF BELTS

2.1 Method of testing

Method of determining the conveyor belt resistance to puncture consists in hitting the belt with increasing force using a puncher. After each impact the belt sample is moved to the another place. The test is considered as terminated, if the puncher penetrates the belt sample. Energy of impact is calculated from the following relationship:

$$E = m \cdot g \cdot h \ \text{[J]} \qquad (1)$$

where: m – mass of puncher [kg],
g – acceleration of gravity [m/s^2],
h – height of puncher fall [m]

After identification of belt damages, the diagram showing relation between size of the damage L [mm] and impact E [J] is plotted. The following values are readout from the diagrams:

- critical energy $\boldsymbol{E_k}$, at which occurs the first damage of belt reaching its core,
- penetration energy $\boldsymbol{E_p}$, at which the belt is penetrated through,
- energy $\boldsymbol{E_L}$, at which the belt damages reach the certain size.

Instead of E_L energy it is possible to calculate the value of average $\boldsymbol{E_{śr}}$ taking into consideration the area under the curve L = f(E). Then:

$$E_{śr} = \frac{\int_{E_k}^{E_p} f(E)dE}{E_p} \qquad (2)$$

The tests are carried out for two types of belt support:

- supporting table and rubber plate – when we simulate the support of rubberized idler,
- without support – when we simulate the hits on the area between idlers.

proizvodnju traka veće operativne trajnosti, što bi za uzvrat proširilo ponudu traka koje se proizvode, kako bi se njihove osobine efikasnije prilagodile određenim operativnim uslovima.

2 ISPITIVANJA OTPORNOSTI TRAKA NA PROBIJANJE

2.1 Metoda ispitivanja

Metoda za određivanje otpornosti transportne trake na probijanje sastoji se iz toga da se traka izlaže probijanju sve većom silom uz pomoć perforatora. Posle svakog udara uzorak trake se pomera na drugo mesto. Smatra se da je ispitivanje završeno onda kada probijač probuši uzorak trake. Energija udara se izračunava putem sledeće formule:

$$E = m \cdot g \cdot h \ \text{[J]} \qquad (1)$$

gde je: m – masa peforatora [kg],
g – ubrzanje gravitacije [m/s^2],
h – visina pada perforatora [m]

Nakon utvrđivanja oštećenja trake, izrađuje se dijagram koji pokazuje odnos između veličine štete L [mm] i udara E [J]. Sa dijagrama se mogu očitati sledeće vrednosti:

- Kritična energija $\boldsymbol{E_k}$, pri kojoj dolazi do prvog oštećenja trake koje dolazi do njenog jezgra,
- Energija penetracije $\boldsymbol{E_p}$, pri kojoj dolazi do proboja trake,
- energija $\boldsymbol{E_L}$, pri kojoj oštećenja trake dostižu određenu veličinu.

Umesto energije E_L moguće je izračunati vrednost prosečne $\boldsymbol{E_{śr}}$ uzimajući u obzir oblast pod krivuljom L = f(E). Tada je:

$$E_{śr} = \frac{\int_{E_k}^{E_p} f(E)dE}{E_p} \qquad (2)$$

Ispitivanja se vrše za sledeće dve vrste potpore trake:

- potporni sto i gumena ploča – kada simuliramo potporu gumiranom nateznom koturu,
- bez potpore – kada simuliramo udare u predelu između nateznih kotura.

When we simulate the hits between idlers, the belt is mounted in the clamping jaws and then stretched by the force equal the 10 % of tear stresses.

Kada simuliramo udare između nateznih kotura, traka se postavlja u stegu (stezna klješta) a zatim se rasteže silom koja je jednaka 10% naprezanja cepanja.

The evaluation of the puncture resistance of specific belt is made basing on tests of two samples: one stretched using the clamping jaws and not supported along the measuring section, and the second, where, along the tested section, the belt is supported by the 500 mm thick rubber plate laying on the stiff table. Six energy values are obtained for each tested sample. While comparing the belts of different construction it is useful to utilize the average values for each tested belt.

Ocena otpornosti na probijanje određene trake vrši se na osnovu ispitivanja dva uzorka: jednog rastegnutog uz pomoć stege i bez oslonca duž dela na kojem se vrši merenje, i drugog uzorka koji je poduprt, duž ispitivane sekcije, gumenom pločom debljine 500 mm položenom na tvrdi sto. Za svaki ispitani uzorak dobija se šest vrednosti energije. U poređenju traka različitog sklopa trebalo bi koristiti prosečne vrednosti za svaku ispitivanu traku.

2.2 Testing stand

Testing stand installed in LTT is presented on figure 1. It consists of the following major elements:

- Tower
- Hydraulic feeder
- Belt stretching set
- Bottom frame with hydraulic cylinders for longwise and crosswise shift of table
- Cart with puncher
- Hoisting winch
- Supporting table

The technical parameters of the stand are as follows:

- Height of cart with puncher fall 0÷3000 mm
- Weight of cart with puncher 50 kg (possibility of increasing up to 70 kg)
- Size of belt sample: width 500 mm, length 1300 mm
- Force of belt stretching 0÷259 kN

2.2 Postolje za ispitivanje

Postolje za ispitivanje instalirano u LTT prikazano je na slici 1. Sastoji se od sledećih glavnih elemenata:

- Toranj
- Hidraulični fider
- Garnitura za rastezanje trake
- Donji okvir sa hidrauličnim valjcima za pomeranje stola po dužini i po širini
- Kolica sa perforatorom
- Čekrk za dizanje
- Potporni sto

Tehnički parametri postolja su sledeći:

- Visina kolica sa perforatorom 0÷3000 mm
- Težina kolica sa perforatorom 50 kg (mogućnost povećanja težine do 70 kg)
- Dimenzije uzorka trake: širina 500 mm, dužina 1300 mm
- Sila rastezanja trake 0÷259 kN

Figure 1 Testing stand for punching the belts
slika 1 Postolje za ispitivanje traka u pogledu probijanja

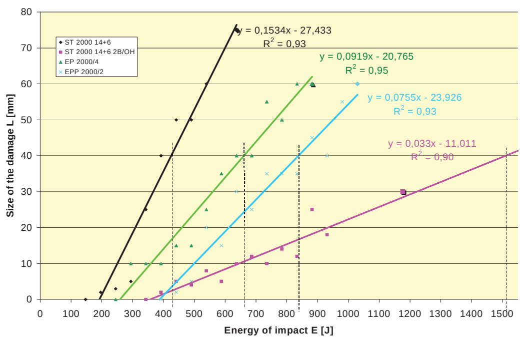

Figure 2 Results of puncture resistance of belts under simulation of hitting between idlers
slika 2 Rezultati otpornosti na probijanje traka u simulaciji udaranja između kotura

Example diagrams using the result of four belts testing are presented on figure 2. The diagrams show the results of tests whith simulation of hitting the belt between idlers. The test results indicate the substantial differences in belts resistance to puncture, depending on their construction as well as the major impact of protecting flitting in belts with steel cords.

The tests demonstrated the high efficiency of some construction solutions, where almost twice bigger puncture resistance was obtained, compared with standard belts without protecting flitting.

3 TESTS OF LONGITUDINAL TEAR RESISTANCE OF CONVEYOR BELTS

3.1 Method of testing

Testing the belts with regard of their resistance to longitudinal cut were carried out abroad in eighties of the twentieth century. They were aimed to develop the belt construction where the cutting resistance causes throwing out the cutting element, its bend or stops the drive of conveyor. This target has not been reached yet. It seems that now it is not possible to produce the conveyor belts having such high cut resistant. Since it is possible to design the belt with very high cut resistance, but its application would be very risky, because in case of longitudinal cutting, its cover might be torn along the big width or it would be totally exfoliated. The belt may be regarded as a good one, when at the high cutting resistance, during the test of longitudinal cut, the covers are not exfoliated at both sides of cutting line. Testing the longitudinal cut resistance of belts in LTT laboratory consists in determining the force necessary to cut them using the special knife. During the test the sample captured at one side by the clamping jaw is moved using the hydraulic cylinder. While the belt is moved, the knife fixed along the belt axis, cuts the belt. The cutting force is recorded. Average value of the force define the cutting resistance of the belt.

3.2 Testing stand

Testing stand is mounted on the basis of horizontal tensile testing machine ZT 40 being one of the LTT laboratory facilities. The beam

Dijagrami dobijeni iz rezultata testiranja četiri trake prikazani su na slici 2. Dijagrami pokazuju rezultate ispitivanja sa simulacijom udaranja trake između kolutova. Rezultati ispitivanja pokazuju suštinske razlike otpornosti traka na probijanje, u zavisnosti od njihovog sastava kao i glavnog udara u zaštitni sloj u trakama sa čeličnom užadi.

Ispitivanja su pokazala veliku delotvornost nekih konstrukcionih rešenja, u kojima je dobijena skoro dva puta veća otpornost na probijanje, u poređenju sa standardnim trakama bez zaštitnog sloja.

3. ISPITIVANJA OTPORNOSTI NA KIDANJE TRANSPORTNIH TRAKA PO DUŽINI

3.1 Metoda ispitivanja

Ispitivanja traka u pogledu njihove otpornosti na cepanje po dužini izvršena su u inostranstvu osamdesetih godina dvadesetog veka. Ona su imala za cilj da se izrade takve transportne trake kod kojih otpornost na prosecanje prouzrokuje izbacivanje sečiva, njegovo savijanje ili zaustavlja pogon transportera. Još uvek nije postignut ovaj cilj. Izgleda da sada nije moguće proizvesti transportne trake koje imaju toliko visoku otpornost na prosecanje. Pošto je moguće projektovati traku sa tako visokim stepenom otpornosti, ali bi njena primena bila veoma rizična, jer bi, u slučaju prosecanja po dužini, njen gornji sloj mogao biti potrgan u većem delu njene širine ili bi mogao biti u potpunosti oljušten. Traka bi se mogla smatrati dobrom, kada pri ispitivanju cepanja po dužini, gornji slojevi nisu oljušteni na obe strane linije cepanja. Ispitivanje otpornosti traka na cepanje po dužini u LTT laboratoriji sastoji se u određivanju sile potrebne za njihovo isecanje pomoću posebnog noža. Tokom ispitivanja uzorak koji je pritegnut stegom s jedne strane pomera se pomoću hidrauličnog valjka. Dok se traka kreće, nož seče traku, pričvršćen duž ose trake. Beleži se sila sečenja. Prosečna vrednost te sile određuje otpornost trake na prosecanje.

3.2 Postolje za ispitivanje

Postolje za ispitivanje se postavlja na osnovu mašine za ispitivanje rastezljivosti ZT 40 koja čini deo postrojenja LTT laboratorije. Poluga sa with cutting knife is jointly mounted to the one of the machine handle. The view of sample examined at the testing stand to establish its cutting resistance is showed on Figure 3.

Testing stand has the following technical parameters:

- Measuring range 100 kN
- Cutting tool with square cross-section, thickness - 6 mm
- Sample size: width 500 mm, length 1300 mm

Example charts showing the course of cutting the belts with steel cords are showed on figure 4

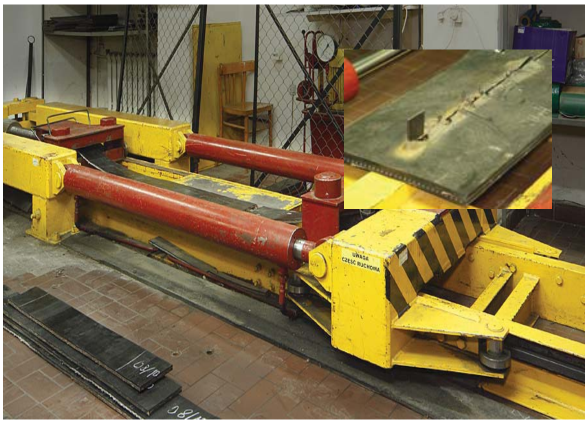

Figure 3 Horizontal ZT 40 tensile testing machine and longitudinal cutting of ST3150 14T+7T belt
slika 3 Horizontalna mašina za ispitivanje rastezljivosti ZT 40 i sečenje po dužini trake ST3150 14T+7T

The increase of cutting resistance of belts with steel cords is achieved by enlarging the thickness of rubber covers and by applying the protective flitting. The best results are obtained when protective flittings are made of cord threads placed transversely in few millimeter intervals. High adhesive resistance of the belt core covers as well as high adhesion of steel cords to the core layer are the additional prerequisites for achieving the positive effect. Implementation of protective flittings gives about 40÷60 % increase of cutting resistance of the belt.

4 SUMMARY

Producers of conveyor belts, operating under increasing competitive conditions are forced to search for new and better solutions. It is obvious that every such solution must go through all

nožem se zajednički postavlja na jednu od ručki mašine. Na slici 3 je prikazan pregled uzorka ispitanog na postolju za ispitivanje kako bi se ustanovila njegova otpornost na prosecanje.

Postolje za ispitivanje ima sledeće tehničke parametre:

- Opseg merenja 100 kN
- Sečivo sa četvrtastim poprečnim profilom, debljine - 6 mm
- Dimenzija uzorka: širina 500 mm, dužina 1300 mm

Na slici 4 prikazani su grafikoni uzorka koji prikazuju tok sečenja traka čeličnom užadi.

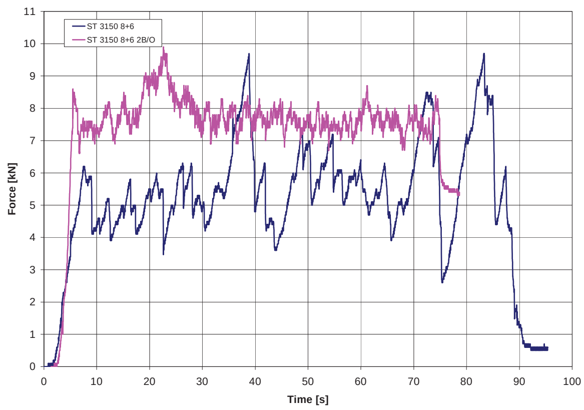

Figure 4 Cutting force of ST 3150 standard belt and with two protective flittings
slika 4 Sila sečenja standardne trake ST 3150 sa dva zaštitna sloja

Povećanje otpornosti traka sa čeličnom užadi na prosecanje postiže se povećavanjem debljine gumenih navlaka i stavljanjem zaštitnog sloja. Najbolji rezultati se dobijaju kada su zaštitni slojevi napravljeni od niti užeta postavljenih poprečno na razmaku od nekoliko milimetara. Visoka adhezivna otpornost gornjih slojeva trake kao i visoka adhezija čelične užadi za jezgreni sloj su dodatni preduslovi za postizanje pozitivnog efekta. Implementacija zaštitnog sloja daje oko 40÷60 % povećane otpornosti trake na prosecanje.

4 ZAKLJUČAK

Proizvođači transportnih traka, koji rade u sve konkurentnijim uslovima, prinuđeni su da traže nova i bolja rešenja. Očigledno je da svako takvo rešenje mora proći kroz sve relevantne testove, i relevant tests, preferably giving the results as quickly as possible. Thus there is a demand for development and modernization of laboratories and testing methods, which may quickly and precisely evaluate the quality and expected lifetime of the product operating under certain working conditions. Moreover the integration of Poland with European Union poses the great challenge with regard of accuracy and complementarity of the laboratory tests. New testing stands are constructed as a results of those requirements.

da po mogućstvu da rezultate što je moguće brže. Prema tome, postoji potreba za razvojem i modernizacijom laboratorija i metoda za ispitivanje, koje mogu brzo i precizno da procecne kvalitet i očekivani rok trajanja proizvoda koji funkcioniše u određenim radnim uslovima. Štaviše, integracija Poljske u Evropsku Uniju predstavlja veliki izazov u pogledu tačnosti i komplementarnosti laboratorijskih testova. Izrađena su nova postolja za ispitivanje kao rezultat tih zahteva.

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Reviewal / Recenzija: prof. dr Miloš Grujić

Acknowledgement

This paper was financially supported by State Committee for Scientific Research 2010–2013 as research project.