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# POLISH REALIZATIONS OF ENERGY - SAVING MINE BELT CONVEYORS

# REALIZACIJA UPOTREBE ENERGETSKI EFIKASNIH RUDNIČKIH TRANSPORTNIH TRAKA U POLJSKOJ

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**Abstract:** *An important problem of reducing energy consumption in the stage of construction and operation of mine belt conveyors is connected with their broad use in the industry. However, this notion is related to a reduction of electric energy consumption for conveyor drive and for production of conveyor components and assemblies (belts, rollers, load-bearing structure etc.). An essential role is played by an increased life of belt conveyors assemblies and components, principally belts. A reduced electric energy consumption results in a decreased $CO_2$ emissions, e.g. electric power station issues 0.285 kg $CO_2$ per 1 kW of installed power, another example – production of 1 kWh in brown coal – fired power station to answer creation of 0.95 kg $CO_2$, production of 1 t steel accounts for 3.2 t $CO_2$ emissions. The subject-matter presented in the paper concerning energy-saving mine belt conveyors installed in a Polish colliery, has a big economic significance and it is important from the point of view of environmental protection.*

**Keywords:** *energy-saving mine belt conveyor, realizations in Polish Colliery*

**Apstrakt:** *Smanjenje utroška električne energije tokom konstrukcije i upotrebe transportnih traka predstavlja bitan problem, imajuci u vidu njihovu široku primenu u industriji. U svakom slučaju, ovo se odnosi na redukciju upotrebe električne energije za pogon transportera i za smanjenje utroška elektirčne energije za proizvodnju delova i komponenti transportera (traka, valjaka, noseće konstrukcije, itd). Produžetak veka trajanja delova i komponenti transportnih traka, naročito traka značajno je uticao na smanjenje utroška električne energije. Usled redukcije upotrebe električne energije došlo je do smanjenja emisije $CO_2$, na primer, električna centarala emituje 0.285 kg $CO_2$ po 1 kW instalisane snage, termoelektrana emituje 0.95 $CO_2$ po 1 kWh, dok se prilikom proizvodnje 1 t čelika emituje 3.2 t $CO_2$. Način upotrebe transortnih traka u rudnicima prezentovan u ovom radu je veoma značajan kako sa ekonomskog aspekta, tako i sa sa aspekta zaštite životne sredine.*

**Ključne reči:** *energetski efikasne transportne trake, realizacija u poljskim rudnicima*

## 1 INTRODUCTION

A problem of energy-saving in the case of belt conveyors will be presented on the base of three conveyors – one installed in the Piast Colliery, the second one operating at the Jankowice Colliery and the third one – at the Marcel Colliery. The technical specification of the conveyors is given in Table 1.

## 1 UVOD

Problem uštede energije u slučaju transportera sa trakom biće prikazan na primeru tri transportera – jednog instaliranog u rudniku uglja Piast, drugog koji radi u rudniku uglja Jankovice i trećeg – u rudniku uglja Marcel. Tehnička specifikacija transportera data je u Tabeli 1.

*Table 1 Technical specification of energy-saving mine belt conveyors*
*Tabela 1 Tehnička specifikacija rudničkih transportera sa trakom koji štede energiju*

| Conveyor | | Belt | | Power of drives | Use of transverse intersection % | Power discriminate kW/m | Bends | | |
|---|---|---|---|---|---|---|---|---|---|
| Length, m Place of installation | Productivity, t/h Transportation height, m | *B*, m type | *v*, m/s | | | | *R* m | Number | |
| | | | | | | | | Hor. | Vert. |
| 2157.8 PV Piast Colliery | 1400 0 | 1.2 GTP 1000/2-2-1-1200 | 3.25 | 7x132 | 30 to 40 | 0.428 (0.306 for 5 motors) | 573* | 1 | 0 |
| 1080 Jankowice Colliery | 2000 +151 | 1.4 ST 3180 | 1.6 3.8 | 4x355 | 56 | 1.315 | 600** | 1 | 3 |
| 1860 Marcel Colliery | 1500 +385 | 1.4 ST 4500 | up to 4.2 | 3x860 | 35 to 46 | 1.387 | – | – | – |
| *horizontal curvature, **spatial arc | | | | | | | | | |

## 2 ENERGY-SAVING BELT CONVEYOR IN THE PIAST COLLIERY

One of the very first curvilinear belt conveyors in Poland was a horizontal conveyor of the PV symbol (Figure 1) installed in the Piast Colliery.

## 2 TRANSPORTER SA TRAKOM KOJI ŠTEDI ENERGIJU U RUDNIKU UGLJA PIAST

Jedan od prvih krivolinijskih transportera sa trakom u Poljskoj bio je horizontalni transporter sa PV oznakom (slika 1), postavljen u rudniku uglja Piast.

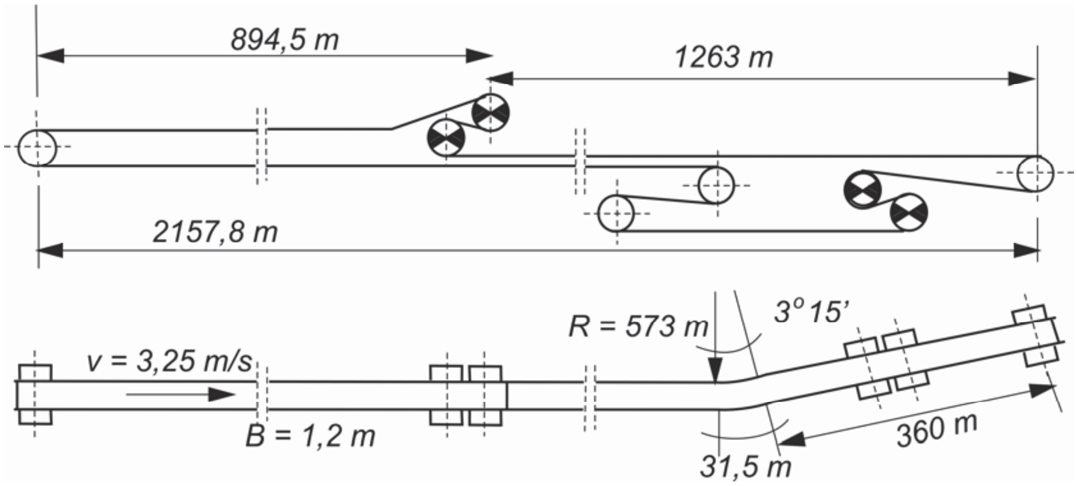



*Figure 1 Schematic diagram of the long belt conveyor with horizontal curve (PV, Piast Colliery)*
*slika 1 Šematski prikaz dugog transportera sa trakom sa horizontalnim krivinama (PV, rudnik uglja Piast)*

A total length of that conveyor was 2157.8 m. The drum dumping drive was installed in the distance of 894.5 m from the return end and the conveyor discharge was situated in the distance of 1263.3 m from the dumping drive. The conveyor drive consisted of seven motors of 132 kW power, three motors out of them were in the dumping drive and four – in the main drive.

Ukupna dužina tog transportera bila je 2157,8 m. Pogon bubnja za odlaganje je postavljen na razdaljini od 894,5 m od povratne stanice a istovarni deo transportera je bio smešten na razdaljini od 1263,3 m od pogona za odlaganje. Pogon transportera sastojao se od sedam motora snage 132 kW, od kojih su tri bila u pogonu za odlaganje a četiri u glavnom pogonu.

Total power of drive motors was overdimensioned and that is why most often only four motors operated; two in the dumping drive and two in the main drive. A soft start of the conveyor was performed by RTSE 200/1 thyristor starters. An average conveyor production rate was 500 t/h and maximal one – 1400 t/h. A belt of 1.2-metre width and of unit weight 21 kg/m was installed in the conveyor.

A horizontal bend was situated in the distance of 360 m from the discharge. Its length was 31.5 m, its radius was 573 m and a deflection angle was equal to 3°15'. Due to that reason a displacement of the conveyor discharge axis from its main longitudinal axis, preceding an entrance of the conveyor in the bend, was 21.35 m. A measured belt speed was 3.25 m/s for an empty conveyor.

Sets of top rollers were installed every 1.5 m and of the bottom ones – every 3.0 m. In total there were 1454 top sets and 719 bottom ones. The rollers were of 133-mm dia. The weight of rotational parts of rollers in a load-bearing set was 27.6 kg, and in a bottom set – 24 kg. A special positioning of sets of rollers was used in the horizontal bend.

The PV conveyor was subject to numerous measurements using the state-of-the-art measurement and recording apparatus [2,5]. In this conveyor a distribution of load on individual drives was subject to Euler law. Table 2 shows it for the main drive.

Ukupna snaga pogonskih motora bila je preuveličana i zbog toga su često radila samo četiri motora; dva u bubnju za odlaganje i dva u glavnom pogonu. Pokretanje sa zadrškom transportera vršili su tiristorski pokretači (starteri) RTSE 200/1. Prosečni proizvodni kapacitet transportera bio je 500 t/h a maksimalni – 1400 t/h. U transporter je bila postavljena traka širine 1,2 metra i specifične težine 21 kg/m.

Horizontalna krivina je bila smeštena na rastojanju od 360 m od istovara. Njena dužina je bila 31,5 m, obim 573 m a ugao otklona je bio jednak 3°15'. Iz tog razloga, pomeranje osovine istovara transportera sa njene glavne osovine po dužini, pre ulaska transportera u krivinu, bilo je 21,35 m. Izmerena brzina trake je bila 3,25 m/s kod praznog transportera.

Setovi gornjih valjaka instalirani su na svakih 1,5 m a donjih – na svaka 3 m. Ukupno je bilo 1454 gornjih setova i 719 donjih. Valjci su bili prečnika od 133 mm. Težina rotacionih delova valjaka u nosećem setu bila je 27,6 kg, a u donjem setu – 24 kg. Posebno pozicioniranje setova valjaka korišćeno je u horizontalnoj krivini.

Transporter PV bio je podvrgnut brojnim merenjima pomoću najsavremenijih uređaja za merenje i snimanje [2,5]. U ovom transporteru raspodela opterećenja na pojedinačnim pogonima podvrgnuta je Ojlerovom zakonu. Ovo je kod glavnog pogona prikazano na Tabeli 2.

*Table 2 Distribution of load on main drive motors of PV belt conveyor*
*Tabela 2 Raspodela opterećenja na glavnim pogonskim motorima transportera sa trakom PV*

| PV empty conveyor, v = 3.25 m/s | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measured power, kW | | Measured belt tension, kN | | Circumferential force kN | | Coefficient of friction belt-drum μ | Belt tension between drums $S_2$, kN | Central angle corresponding to an effective surrounding arch deg | |
| $N_1$ | $N_2$ | discharge $S_w$ | tensioning $S_n$ | 1 | 2 | | | $\alpha_1$ | $\alpha_2$ |
| 54.2 | 52.8 | 70.3 | 47.3 | 13.01 | 12.185 | 0.25 | 59.585 | 44.24 | 52.7 |
| PV conveyor with run-of-mine 105 600 kg, v = 3.19 m/s | | | | | | | | | |
| 74.1 | 64.2 | 83.2 | 42.4 | 20.445 | 16.1 | 0.25 | 58.6 | 68.8 | 74.03 |
| Index 1,2 is related to the first drum tensioned from the dumping jib, 2 – to the second drive drum | | | | | | | | | |

$W_2 = N_2 \cdot 1000 \cdot \eta / v$ N; $e^{\mu\alpha_2} = (W_2 / S_n) + 1 \Rightarrow \alpha_2$;

$S_2 = S_n + W_2$ N; $W_1 = N_1 \cdot 1000 \cdot \eta / v$ N; $e^{\mu\alpha_1} = (W_1 / S_2) + 1 \Rightarrow \alpha_1$

The results of measurements were used to determine the value of the fictitious coefficient of friction *f* (according to DIN22107) for an empty conveyor as well as a loaded one. The load of run-of-mine was 69,6 t and 105,5 t. The results are presented in Table 3.

Rezultati merenja su korišćeni da bi se odredila vrednost fiktivnog koeficijenta trenja *f* (prema DIN22107) kako kod praznog transportera tako i kod punog. Teret iz rudnika bio je 69,6 t i 105,5 t. Rezultati su prikazani u Tabeli 3.

*Table 3 Determining fictitious coefficient of friction for belt conveyor PV (Piast Colliery)*
*Tabela 3 Određivanje fiktivnog koeficijenta trenja kod transportera sa trakom PV (rudnik uglja Piast)*

| Operating conditions of conveyor t | Measured | | Frictional resistance caused by belt centering* | | | Lengths coefficient *C*(–)*** | Fictitious coefficient of friction *f*(–) |
|---|---|---|---|---|---|---|---|
| | total power kW | belt velocity m/s | summed kW | bottom strand *N*/z** | top strand *N*/z** | | |
| Empty | 184 | 3,25 | 44,7 | 10 | 1,2 | 1,02 | 0,0196 |
| With run-of-mine 69,6 t | 193 | 3,2 | 48,15 | 10 | 3,1 | 1,1 | 0,015 |
| With run-of-mine 105,6 t | 226 | 3,19 | 50,6 | 10 | 4.0 | 1,1 | 0,0164 |

*calculated a prof. Vierling formula; **N/z – N per roller set; *** according DIN 22101
*izračunato po formuli prof. Virlinga; **N/z – N po setu valjaka; *** prema DIN 22101

Additional friction caused by centering action of side rollers was calculated for a full range of top and bottom sets using the formula by prof. Vierling. The chart depicting the change of coefficient *f* as a function of the load of the conveyor is presented on Figure 2.

Dodatno trenje prouzrokovano delovanjem centriranja bočnih valjaka izračunato je za ceo niz gornjih i donjih setova pomoću formule po prof. Virlingu. Dijagram koji opisuje promenu koeficijenta *f* kao funkcije opterećenja transportera prikazan je na slici 2.

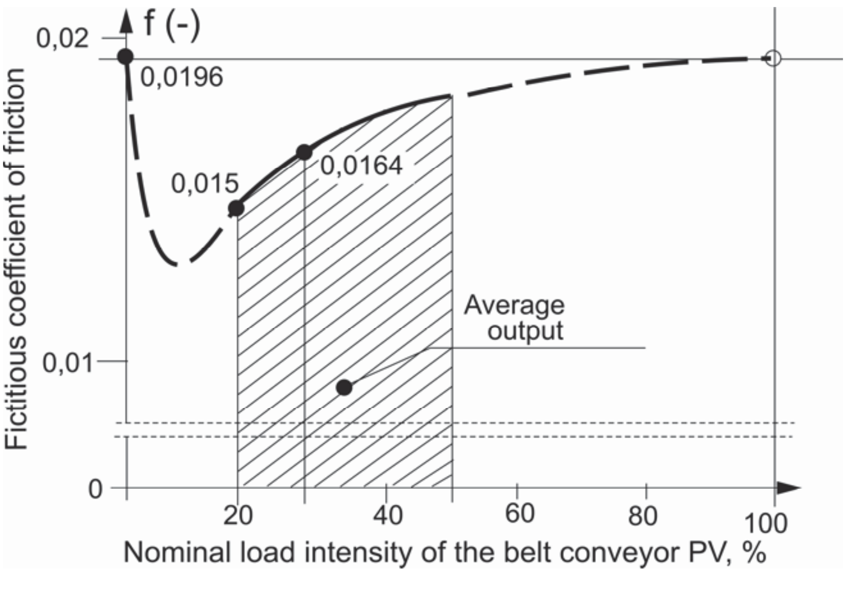



*Figure 2 Dependence of the f coefficient on the unit nominal output of belt conveyor PV (Piast Colliery)*
*slika 2 Zavisnost koeficijenta od jediničnog nominalnog izlaza transportera sa trakom PV PV (rudnik uglja Piast)*

Diagram on the Fig. 2 concerning belt conveyor in the summered unit mass of belt and rotational unit mass of top idler per unit mass of run-of-mine is 1:4.5

After having changed the conveyor design, the centering sets were used only in 35.97% of the load – bearing sets. That measure contributed to a reduction of power consumption in the belt conveyor of symbol PVb. For an empty conveyor the power consumption was 176.3 kW and the calculated value of the $f$ coefficient decreased to the value $f$ = 0.0191. Efficiencies of electric motors had a certain impact on given results.

Small values of a fictitious coefficient of friction $f$, determining main resistances, calculated on the base of the results of numerous industrial measurements of the PV belt conveyor, resulted from: a small use of the nominal transverse intersection of the material handled on the belt (on average 30 – 40%); a use of the belt with multi-ply cord and covers made of chloroprene (CR) rubber of small rolling resistance at denting [2], produced by FTT Wolbrom J.S.C.; constant ambient temperature in the range of 25°C; the belt conveyor route correctly laid out; relatively big belt initial tension (a sag at a big conveyor length was smaller than 1%) and the material handled of a relatively small internal friction.

Energy-saving feature of the PV conveyor resulted from: a small value of fictitious coefficient of friction; a low strength of used belt; increased belt speed, a use of thyristor starters; use of drum intermediate drive; increased length of the belt conveyor with curvature; a use of roller sets of dia 133 mm and spacing of 1.5 m in the top strand and of 3.0 m in the bottom strand and an inclination of side rollers in the load-bearing strand at angle of 35°.

## 3 ENERGY-SAVING BELT CONVEYOR AT JANKOWICE COLLIERY

Energy-saving arterial inclined and inter-level belt conveyor with a spatial curvature, installed in the incline of the Jankowice Colliery, has four single drum drives with squirrel-cage motors of 355 kW power, which are controlled by current frequency converters of PPC 2/3 type. The belt speed, changed in relation to the amount of the run-of-mine on the belt, varies from 1.6 to 3.8 m/s.

Dijagram na slici 2 koji se tiče transportera sa trakom u zbirnoj jediničnoj masi trake i rotacione jedinične mase gornjeg nateznog koluta po jediničnoj masi iskopane rude je 1:4,5.

Pošto je promenjen dizajn transportera, setovi za centriranje su korišćeni samo u 35,97% nosećih setova. Ta mera je doprinela smanjenju potrošnje energije u transporteru sa trakom oznake PVb. Kod praznog transportera potrošnja energije je bila 176,3 kW a izračunata vrednost koeficijenta $f$ smanjila se na vrednost $f$ = 0,0191. Učinci elektromotora imali su određeni uticaj na date rezultate.

Male vrednosti fiktivnog koeficijenta trenja $f$, koje određuju glavne otpore, izračunate na osnovu rezultata brojnih industrijskih merenja transportera sa trakom PV, nastale su usled: malog korišćenja nominalnog poprečnog preseka materijala na traci (prosečno 30 – 40%); korišćenja trake sa višestrukim užetom i omotom od hloroprenske (CR) gume malog otpora na kotrljanje kod stvaranja ulegnuća [2], proizvedene od strane FTT Wolbrom J.S.C.; konstantne okolne temperature oko 25°C; trase transportera pravilno postavljene; relativno velikog početnog zatezanja trake (uleganje kod velike dužine transportera bilo je manje od 1%) i materijala koji se prenosi relativno malog unutrašnjeg trenja.

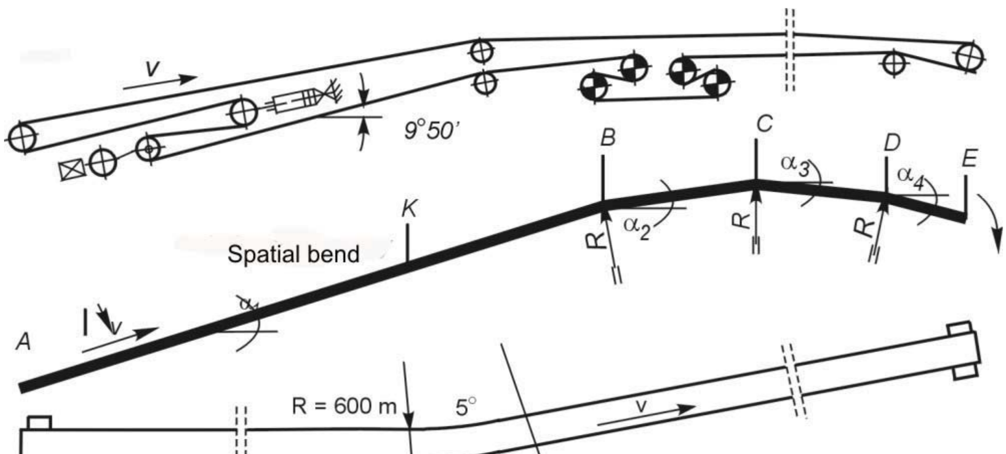
Osobina PV transportera da štedi energiju potiče od: male vrednosti fiktivnog koeficijenta trenja; male čvrstoće korišćene trake; povećane brzine trake, korišćenja tiristorskih pokretača; korišćenja posrednog pogona bubnja; veće dužine transportera sa krivinom; korišćenja setova valjaka prečnika 133 mm i razmaka od 1,5 m u gornjem kraju i 3 m u donjem kraju i nagibom bočnih vlajaka u nosećem kraju pod uglom od 35°.

## 3 TRANSPORTER SA TRAKOM KOJI ŠTEDI ENERGIJU U RUDNIKU JANKOVICE

Transporter sa trakom koji štedi energiju – arterijalni, uskopni i sa među-nivoima, sa prostornom krivinom, instaliran na padini rudnika uglja Jankovice, ima četiri pogona sa jednim bubnjem i sa kratkospojnim motorima snage 355 kW, kojima upravljaju frekvencijski konvertori tipa PPC 2/3. Brzina trake, koja se menja zavisno od količine iskopine na traci, varira od 1,6 do 3,8 m/s.

This conveyor, of Bogda 1400 type has the length of 1080 m and the lift of 151 m. Three convex bends of the radius $R$ = 200 m and one spatial bend of the radius $R$ = 600 m and deflection of 5° (Fig. 3) are in the conveyor. The conveyor is equipped with anti-return couplings and hydraulic brake sets, which are supplied from a hydraulic power-pack. It is also equipped with an automatic tensioning station, situated near its return-end. The colliery, installing this belt conveyor, approved of the concept and calculations, made by the Author, which concerned a unique, in the world scale inclined conveyor with a spatial bend. The belt ST 3150-10/8 with a breaker made of steel mesh in the load-bearing cover (made by FTT Stomil Wolbrom J.S.C.) of the width 1.4 m was installed in the conveyor [1]. The belt covers were made of material on the base of chloroprene caoutchouc. For the production rate of 2000 t/h a use of nominal transverse intersection of handled material on the belt is 56%. The power of drive motors for this production rate reaches 1100 kW, which accounts for 77.5% of installed power.

Ovaj transporter, tipa Bogda 1400 ima dužinu od 1080 m i uspon od 151 m. U transporteru se nalaze tri konveksne krivine prečnika $R$ = 200 m i jedna prostorna krivina prečnika $R$ = 600 m i otklona od 5° (Sl. 3). Transporter je opremljen anti-povratnim spojnicama i setovima hidrauličnih kočnica, koje se napajaju putem hidrauličnog agregata. Takođe je opremljen automatskom stanicom za zatezanje, smeštenom blizu svoje povratne stanice. Rudnik uglja, time što instalira ovaj transporter sa trakom, odobrava koncept i proračune, koje je izradio autor ovog rada, a koji se tiče, jedinstvenog u svetu, uskopnog transportera sa prostornom krivinom. U transporter je ugrađena traka ST 3150-10/8 sa prekidačem od čelične mrežice u zaštitnom nosećem sloju (proizvedenog od strane FTT Stomil Wolbrom J.S.C.) širine 1,4 m [1]. Zaštitni slojevi trake su izrađeni od materijala na bazi hloroprenskog kaučuka. Pri brzini proizvodnje od 2000 t/h upotreba nominalnog poprečnog preseka materijala koji se prevozi na traci iznosi 56%. Snaga pogonskih motora kod ove brzine proizvodnje dostiže 1100 kW, što čini 77,5% instalisane snage.




| Length of section, m | Inclination angle to horizon | Convex bend radius, m | Bend middle angle | Length of bend, m |
|---|---|---|---|---|
| AK – 660 | $\alpha_1$ = 9°50′ | | | |
| AB – 894 | $\alpha_1$ = 9°50′ | | | |
| BC – 75 | $\alpha_2$ = 4°55′ | B – 200 | 4°55′ | 17.14 |
| CD – 63 | $\alpha_3$ = 1°47′ | C – 200 | 4°55′ | 17.14 |
| DE – 38 | $\alpha_4$ = 7°06′ | D – 200 | 5°06′ | 19.52 |

*Figure 3 Schematic diagram of inclined belt conveyor of Bogda 1400 type with spatial bend in Jankowice Colliery*

*slika 3 Šematski prikaz uskopnog transportera sa trakom tipa Bogda 1400 sa prostornom krivinom u rudniku uglja Jankovice*

Such a small power consumption for a drive results from small values of the fictitious coefficient of friction *f*, which on the base of measurements and calculations for the belt speed of 1.1 m/s is 0.011 and for 3.15 m/s – 0.018.

During the top period when the production rate was 3000 t/h and the belt speed was 3.8 m/s, the power of drive motors reached 1600 kW. An overflow of the rated power was about 13%.

The energy-saving feature of this conveyor results from: a use of motors controlled by current frequency converters which contribute to nearly arithmetic distribution of load on individual driving drums [2,3]; small values of fictitious coefficient of friction due to 50% filling with the run-of-mine of the nominal intersection meant (acc. to standards) for a construction of a handled material heap, which contributes to a reduction of the rolling resistance at denting (Fig. 4) and continually increasing belt tensioning force, causing a quick decrease in the belt deflection (which in the lift range of about 18 m is already smaller by 1%), in the result of which the belt inflection resistances and the run-of-mine undulation resistances decrease significantly; the belt with the steel cord, the breaker and the running cover made of the material based on chloroprene caoutchouc of a reduced rolling friction resistance at denting (in the temperature of about 25°C) a use of sets of rollers of 133-mm dia, an inclination of side rollers 35° and their spacing 1.5 m; a transportation of the run-of-mine of relatively small internal friction; an increased belt life (Table 4), which results among others, from soft starts and braking of the conveyor, a change of the belt speed in the function of the amount of the run-of-mine on the belt, a correct rectilinearity, a proper construction of vertical bends and of the spatial bend, a reduced consumption of electric energy for the conveyor drive (according to tests an average reduction was 0.55 kWh/t of handled run-of-mine, which during the period of the belt life gave about 1.2 mio kWh and a reduction of the $CO_2$ emissions in the number of several hundred tons by power plants.

Tako mala potrošnja energije u pogonu potiče od malih vrednosti zamišljenog koeficijenta *f*, koji, na osnovu merenja i proračuna iznosi 0,011 pri brzini trake od 1,1 m/s, a pri brzini od 3,15 m/s - 0,018.

Tokom najproduktivnijeg perioda, kada je brzina proizvodnje iznosila 3000 t/h a brzina trake 3,8 m/s, snaga pogonskih motora je dostizala 1600 kW. Višak nominalne snage je iznosio oko 13%.

Osobina uštede energije ovog transportera potiče od: korišćenja motora kojima upravljaju frekvencijski konvertori koji doprinose skoro aritmetičkoj raspodeli opterećenja na pojedinačne pogonske bubnjeve [2,3]; malih vrednosti fiktivnog koeficijenta trenja zbog ispunjavanja nominalnog preseka sa 50% iskopine (prema standardima) usled gomilanja materijala koji se prevozi, što doprinosi smanjenju otpora na kotrljanje kod ulegnuća (sl. 4) i neprestano povećanje sile zatezanja trake, što prouzrokuje brzo smanjenje otklona trake (što kod podizača od oko 18 m predstavlja već manje za 1%), a što daje da se otpori na savijanje trake i otpori na povijanje iskopine značajno smanje; traka sa čeličnim užetom, prekidačem i zaštitnim slojem napravljeni su od materijala na bazi hloroprenskog kaučuka smanjenog otpora na trenje pri kotrljanju kod ulegnuća (na temperaturi od oko 25°C) korišćenje kompleta valjaka prečnika od 133-mm, nagib bočnih valjaka 35° i njihovo rastojanje 1,5 m; transport iskopine relativno malog unutrašnjeg trenja; povećani rok trajanja trake (Tabela 4), što potiče od, između ostalog, pokretanja sa zadrškom i kočenja transportera, promene brzine trake u funkciji količine iskopine na traci, tačnog pravougaonog oblika, ispravne konstrukcije vertikalnih krivina prostorne krivine, smanena potrošnja električne energije kod pogona transportera (prema testiranjima prosečno smanjenje je bilo 0,55 kWh/t iskopine kojom se rukuje, što je tokom perioda upotrebe trake dalo oko 1.2 mio kWh i smanjenje emisije ugljendioksida u nekoliko stotina tona proizvedenim u elektranama.

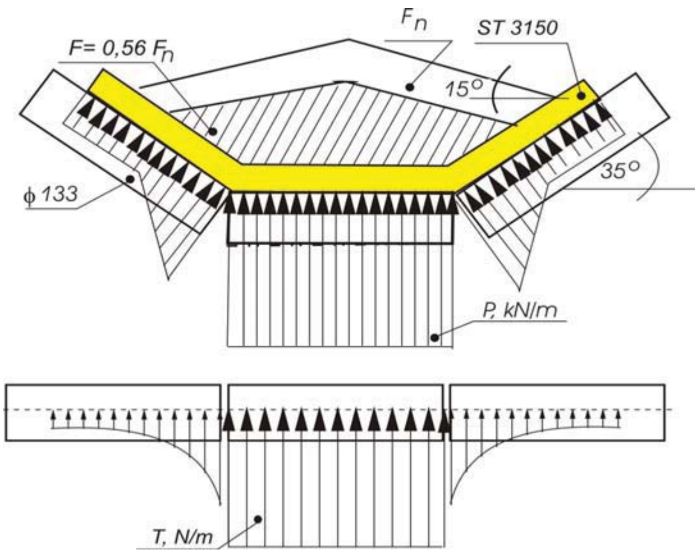



*Figure 4 Distribution of the vertical load on the rollers set and distribution of rolling friction resistance by 56% use of the nominal transverse intersection and for belt bottom covers made of chloroprene rubber (Jankowice Colliery)*
*slika 4 Distribucija vertkalnog opterećenja na valjcima i distribucija otpora na kotrljajno trenje za 56% upotrebe nominalnog poprečnog preseka i za zaštitni donji sloj trake izrađenog od hloroprenske gume (rudnik uglja Jankovice)*

***Table 4*** *Life of GTP ST 3150-10/8 belt operating in Jankowice Colliery*
*Tabela 4 Vek upotrebe trake GTP ST 3150-10/8 koja funkcioniše u rudniku uglja Jankovice*

| Amount of handled run-of-mine, mio tons | Belt operational period, years | Number of performed cycles | Belt conveyor | | | |
|---|---|---|---|---|---|---|
| | | | type of drive | length m | power kW | belt speed m/s |
| ~ 16.0 | 7.5 | about 227 000 | Bogda | 1080 | 4x1x355 | 1.6÷3.8 |

## 4 MARCEL COLLIERY–ENERGY-SAVING MINE BELT CONVEYOR IN TRANSPORT INCLINE FROM THE LEVEL – 400 M TO THE SURFACE

A state-of-the-art belt conveyor (Fig. 5) was implemented in the Marcel Colliery in March 2008 for handling the run-of-mine in the amount of about 10 000 t/d (maximally 1500 t/h) using a transport incline from the level -400 m in the marklowicka part to the surface, to the coal preparation plant. Annually 2 mio tons of coal net at impurities from 20 to 25% are handled by this conveyor. In this area three longwall faces are in operation (in 2010, one of them has a production rate from 6000 to 8000 t/d). After the year 2018 till the year 2034 the annual production will increase to 2.5 mio tons net at average impurities of 23%. The belt conveyor will handle about 12 500 t/d. Marcel run-of-mine conveying is one of the most advanced systems of its type in Europe.

## 4 RUDNIK UGLJA MARCEL – RUDNIČKI TRANSPORTER SA TRAKOM KOJI ŠTEDI ENERGIJU U TRANSPORTNOM SKOPU SA NIVOA -400 M KA POVRŠINI

Najsavremeniji transporter sa trakom (Sl.5) bio je primenjen u rudniku uglja Marcel u martu 2008. godine u cilju rukovanja iskopine u iznosu od oko 10 000 t/d (maksimalno 1500 t/h) pri transportnom uskopu sa nivoa -400 m u marklovičkom delu ka površini, do postrojenja za pripremu uglja. Godišnje se ovim transporterom dopremi 2 miliona tona uglja čistoće od 20-25%. U ovoj oblasti u pogonu su tri široka okna (godine 2010. jedan od njih ima brzinu proizvodnje od 6000 do 8000 t/d). Nakon 2018. godine do 2034. godišnja proizvodnja će se povećati do 2,5 mil. tona rude čistoće 23%. Transporter sa trakom će dopremiti oko 12 500 t/d. Transport rudne iskopine u Marcel-u je jedan od najnaprednijih sistema ove vrste u Evropi.

In the first 24 months of exploitation the belt conveyor handled failure-free 5.266 million t run-of-mine.

A conceptional design project of the arterial inclined belt conveyor and of its mechatronic systems (automation, control and visualization) has been elaborated by the Author [4] in collaboration with Prof. A. Lutyński. The new conveying system of run-of-mine at Marcel Colliery makes mining operations more flexible and helps considerably cut the overall operating costs.

U prva 24 meseca eksploatacije, transporter sa trakom je dopremio bez greške 5,266 miliona tona iskopine.

Projektni dizajn arterijskog uskopnog transportera sa trakom i njegovih mehatronskih sistema (automatizacija, upravljanje i nadgledanje) izradio je autor [4] ovog rada u saradnji sa prof. A. Lutinskim. Novi transportni sistem iskopine u rudniku Marcel čini rudarske aktivnosti fleksibilnijim i značajno pomaže u smanjenju ukupnih operativnih troškova.

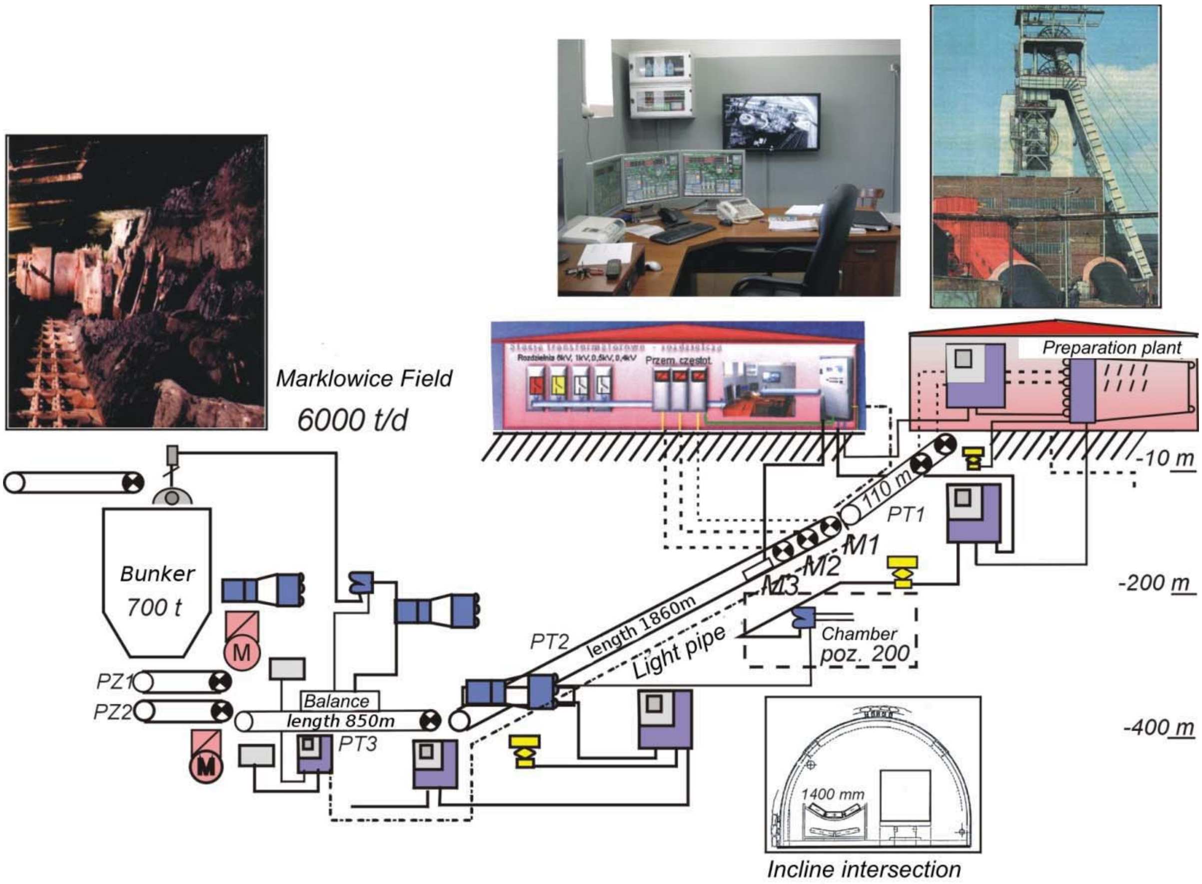



*Figure 5 Schematic diagram of inclined belt conveyor equipped with control, automation and visualization systems (Marcel Colliery 2008).*
*slika 5 Šematski prikaz uskopnog transportera sa trakom opremljenog sistemima za upravljanje, automatizaciju u nagledanje (rudnik Marcel, 2008).*

The conveyor length is 1860 m at the inclination of +12°. The width of the slow-burning belt with steel cord and metal breaker in the load-bearing cover, of the strength 4500 N/mm is 1400 mm and its unit weight reaches 81 kg/m. The parameters of this belt are as follows: type 1400 ST 4500 10+8 TG 1 W/O, steel cord of 9.3 mm dia, the cord pitch is 16 mm, 1 W/O denotes that the belt has a metal reinforcement in the

Dužina transportera iznosi 1860 m pri nagibu od +12°. Širina sporo pokretne trake sa čeličnim užetom i metalnim prekidačem u nosećem zaštitnom sloju, jačine 4500 N/mm, iznosi 1400 mm a njena specifična težina dostiže 81 kg/m. Parametri ove trake su sledeći: tip 1400 ST 4500 10+8 TG 1 W/O, čelično uže prečnika 9,3 mm, obim užeta je 16 mm, 1 W/O označava da traka ima metalno ojačanje u nosećem omotaču koji se load-bearing cover made of cord having 1.55 mm dia. The belt covers are made of material based on chloroprene cautchouc. The sets of rollers conducting the belt top strand have side rollers inclined at the angle of 30°. Spacing of load-bearing sets is 1.5 m and of the bottom ones – 3.0 m. Rollers are of 133 mm dia. The belt speed changes from 0 to 4.2 m/s. At present, the most often used speed is 2.9 m/s. Three motors, each of the power 860 kW controlled with voltage frequency converters (made by ABB Company) are used for driving the conveyor. The drives are equipped with mechanical brakes and counter-return couplings. A surge bunker of the run-of-mine of the capacity 800 t, situated in series with the inclined conveyor, plays a very advantageous role in an operation of the inclined conveyor of variable belt speed ($v$ = var). Unloading of the run-of-mine from the bunker is controlled by a variable speed of chains of two scraper conveyors (feeders), whose driving motors are controlled by frequency converters. These feeders operate alternately.

A motion of an empty belt conveyor with the speed of 2.9 m/s requires a power consumption of about 430 kW; such value of the power 430/3 = 143.3 kW results from the motor efficiency, which for a power relation of 0.17 is about 37%. This power is distributed equally onto three driving motors. It results from a measurement of the current intensity consumed by these motors: motor 1 – 480 A, motor 2 – 480 A and motor 3 – 482 A. Deviations in current intensity measurement for individual motors during their operation are minimal and they vary from 2 to 3 A.

At the production rate of about 1050 t/h the run-of-mine unit weight on the conveyor is 100 kg/m and for the belt speed 2.9 m/s, the power used for handling the run-of-mine is 1574 kW (61% of installed power). Filling of the transverse intersection nominal surface of the run-of-mine heap (0.224 $m^2$) on the belt is about 36%. Such a small filling contributes to a decrease of the rolling resistance at denting. In this case coefficient is $f$ = 0.012. For the production rate of 1210 t/h and the belt speed of 3.314 m/s, indispensable power for a conveyor motion is 1780 kW (69% installed power) and $f$ = 0.0145. For the rated output 1500 t/h and the belt speed of 3.5 m/s, indispensable power for the conveyor drive is about 2055 kW, and filling of the transverse intersection nominal surface of the

sastoji od užeta prečnika 1,55 mm. Omotač trake je izrađen od materijala zasnovanom od hloroprenskog kaučuka. Setovi valjaka koji vode gornji kraj trake imaju bočne valjke koji su nagnuti pod uglom od 30°. Rastojanje između nosećih delova je 1,5 m a donjih delova 3 m. Prečnik valjaka je 133 mm. Brzina trake varira od 0 do 4,2 m/s. U ovom trenutku, najviše se koristi brzina od 2,9 m/s. Tri motora, svaki snage 860 kW kojima upravljaju naponski frekventni konvertori (proizvedeni od strane ABB Kompanije) koriste se za pogon ovog transportera. Pogoni su opremljeni mehaničkim kočnicama i protiv-povratnim spojnicama. Egalizacioni bunker iskopine kapaciteta od 800 t, smešten u nizu kod uskopnog transportera, igra veoma značajnu ulogu u radu uskopnog transportera varijabilne brzine trake ($v$ = var). Istovarom iskopine iz bunkera upravlja se putem dva grabuljara (fider) promenljive brzine, čijim pogonskim motorima upravljaju frekventni konvertori. Ovi fideri rade naizmenično.

Kretanje praznog transportera sa trakom brzinom od 2,9 m/s zahteva potrošnju energije od oko 430 kW; ta vrednost snage 430/3 = 143,3 kW proističe iz iskorišćenosti motora, koja iznosi oko 37% za odnos energije od 0,17. Ova energija se ravnomerno raspodeljuje na tri pogonska motora. Ona proističe iz merenja intenziteta struje koju potroše ova tri motora: motor 1 – 480 A, motor 2 – 480 A i motor 3 – 482 A. Odstupanja u merenju intenziteta struje kod pojedinačnih motora tokom njihovog rada su minimalna i kreću se od 2 do 3 A.

Pri brzini proizvodnje od oko 1050 t/h specifična težina iskopine na transporteru je 100 kg/m a za brzinu trake od 2,9 m/s, snaga koja je upotrebljena za dopremu iskopine je 1574 kW (61% instalisane snage). Popunjenost nominalne površine poprečnog preseka iskopine (0,224 $m^2$) na traci je oko 36%. Tako mala popunjenost dovodi do smanjenja otpora na kotrljanje pri uleganju. U ovom slučaju koeficijent je $f$ = 0.012. Pri brzini proizvodnje od 1210 t/h i brzini trake od 3,314 m/s, neophodna snaga za kretanje transportera je 1780 kW (69% instalisane snage) i $f$ = 0,0145. Pri nominalnom učinku 1500 t/h i brzini trake od 3,5 m/s, neophodna snaga za pogon transportera iznosi oko 2055 kW, a ispunjenost nominalne površine poprečnog preseka materijalom koji se transportuje na traci material handled on the belt reaches 45%. This data comes from automatic recording of the conveyor drive parameters. For this example coefficient $f$ = 0.015. The information about the belt conveyor operation in the number 3200 is recorded and stored in the energy-mechanical dispatch room.

For the production rate of 1500 t/h the belt tension in the discharge drive area equals 760 kN, however for unloaded belt the value of this tension is in the range of 300 kN. For loosening the belt on the drums special hydraulic equipment is used. For a given rated output a safety coefficient of the belt in a steady motion is about 8. Then on the belt there are 270 t of the run-of-mine. After having stopped the conveyor at this condition, its following start may cause certain problems.

It should be noticed that the efficiencies of the system: motor-voltage frequency converter and the gear-box have a big impact on the given values of power consumption for a belt conveyor drive.

A cost of driving a transport working and equipping it with a belt conveyor and toothed floor-mounted railway for a transportation of materials and personnel was 90 mio PLN and it was a dozen or so times lower than the costs which would have been borne if a new vertical production shaft had been constructed and a few times lower if two belt conveyors instead of one had been used in the incline.

An energy-saving advantage of a long, inclined mine conveyor in the Marcel Colliery results from: a very elastic run-of-mine conveying system; a use of voltage frequency converters for controlling the motors of high power, ensuring among others an arithmetical distribution of load on individual motors and a control of the belt speed and with system of continuous belt tension assures long life of belt; a small belt speed lengthening time of the belt cycle and its life; a small filling of the transverse intersection of the run-of-mine heap on the belt (from 0 to 54%), which has an impact on a reduction of the fictitious coefficient of friction $f$ (acc. to DIN 22101); continually increasing belt tension from the dumping return end to the discharge drive, due to which a belt sag among sets of rollers (a value of this sag varies from several-thousandth to ten-thousandth metre) quickly decreases and in the result the resistances of the belt contraflexure as well as the run-of-mine undulation resistances,

dostiže 45%. Ovi podaci proističu od automatskog evidentiranja parametara pogona transportera. Za potrebe ovog primera koeficijent je $f$ = 0.015. Informacije o radu transportera sa trakom u broju 3200 evidentiraju se i čuvaju u energetsko-mašinskoj prostoriji za otpremu.

Pri brzini proizvodnje od 1500 t/h naprezanje trake u području pogona istovara iznosi 760 kN, međutim kod neistovarene trake vrednost ovog naprezanja iznosi 300 kN. Za popuštanje trake na bubnjevima koristi se specijalna hidraulična oprema. Za dati nominalni učinak koeficijent bezbednosti trake u stabilnom kretanju iznosi oko 8. Zatim na traci ima oko 270 t iskopine. Nakon što se transporter zaustavi u ovom stanju, njegovo ponovno pokretanje može proizvesti izvesne probleme.

Treba imati na umu da produktivnost sistema – motornog naponskog frekventnog konvertora i menjača brzina ima veliki uticaj na date vrednosti potrošnje energije kod pogona transportera sa trakom.

Troškovi pokretanja transporta i opremanje istog transporterom sa trakom i zupčastom podnom železnicom za transport materijala i osoblja iznosili su 90 miliona PLN (poljska valuta – zlatnik, prim.prev), i to iznosi desetak puta manje od troškova koji bi nastali kada bi se izgradilo novo vertikalno okno, a nekoliko puta manje ukoliko bi se u uskopu koristila dva transportera umesto jednog.

Prednost dugog, uskopnog transportera sa trakom, u pogledu uštede energije, u rudniku uglja Marcel proizilazi iz: veoma elastičnog sistema za transport iskopine; korišćenje naponskog frekventnog konvertora za upravljanje motorima velike snage, što obezbeđuje, između ostalog, srazmernu distribuciju opterećenja na svaki motor i upravljanje brzinom trake a kod sistema sa kontinualnim naprezanjem trake omogućava dug vek upotrebe trake; pri tome male brzine trake produžuju vreme ciklusa trake i njen vek trajanja; mala ispunjenost poprečnog preseka gomilama iskopine na traci (od 0 do 54%), što ima uticaj na smanjenje zamišljenog koeficijenta trenja $f$ (prema DIN 22101); stalno povećanje zatezanja trake od povratne stanice istovara do pogona istovara, zbog čega se uleganje trake između valjaka (vrednost ovog uleganja se kreće od nekoliko hiljada do desetina hiljada metara) brzo smanjuje što dovodi do smanjenja otpora na kontra-savijanje kao i which are incorporated in the fictitious coefficient of friction *f*, decrease; optimized constant filling belt conveyor with run-of-mine (controlled discharge from the bunker); a limited number of the belt contraflexures on driving and other drums; a sophisticated implementation of mechatronic systems for an operation and exploitation of the conveyor, in particular for controlling the belt speed and an operation of electronic scales; a reduction of costs for an installation of one conveyor instead of two as it was in the former project and a location of the electrical power switching station and frequency converters on the surface of the colliery; a remote control and visualization of belt conveyor contributed to reduction the level of employment and to increase of labour safety

otpornost na talasanje (povijanje), koja je sastavni deo fiktivnog koeficijenta trenja *f*; optimizovano punjenje transportera iskopinom (kontrolisano pražnjenje bunkera); ograničen broj kontra-savijanja trake na pogonskim i drugim bubnjevima; sofisticirana primena mehatronskih sistema za rad i eksploataciju transportera, naročito za kontrolisanje brzine trake i rad elektronskih vaga; smanjenje troškova za instalaciju jednog transportera umesto dva kao što je bilo u prethodnom projektu i lokacija električne centrale i frekvencijskih konvertora na površini rudnika uglja; daljinsko upravljanje i nadgledanje transportera sa trakom doprinelo je smanjenju nivoa uposlenosti i povećanju bezbednosti na radu.

## 5 GENERAL REMARKS AND CONCLUSIONS

As it has been shown in the paper many mine belt conveyors can be ranked as energy-saving. Belts both with multi-ply cord as well as with steel cord made by FTT Wolbrom, J.S.C. make a big contribution. Since these belts have the running covers made of the material based on chloroprene cautchouc (CR) characterized by a small resistance to rolling friction at denting in the temperature which occurs in the majority of underground workings in collieries. An increased belt tension in medium-length belt conveyors contributes to that, limiting in a decisive way the belt sag among the sets of rollers, which is smaller than 1%. Increased energy-saving features are obtained due to a usage of motors controlled by frequency converters – it has been shown through a comparison of the belt conveyor from the Piast Colliery with the belt conveyor from the Jankowice Colliery. An increased life of the belt and other conveyor components, resulting from soft-starts, soft-braking, a change of the belt speed, in particular an obtained arithmetical load distribution on the individual drives in the place of distribution according to Euler law, play a decisive role in this case.

In traditional design constructions of belt conveyors an incomplete use of transverse intersection nominal surface of the material handled on the belt, relatively small, internal friction of the coal run-of-mine and also an inclination of the side rollers of 30° or 35° have a certain impact on energy-saving. A variable stream of the material handled supplied onto the

## 5 OPŠTE NAPOMENE I ZAKLJUČCI

Kao što je u radu već prikazano, mnogi rudnički transporteri sa trakom se mogu svrstati u transportere koji štede energiju. Tome doprinose u velikoj meri kako trake sa višestrukim užetom tako i sa čeličnim užetom, koje proizvodi kompanija FTT Wolbrom, J.S.C. Pošto ove trake imaju pokretne omotače od materijala na bazi hloroprenskog kaučuka (CR) koje karakteriše mali otpor na kotrljajno trenje pri uleganju na temperaturi koja nastaje u većini podzemnih prostorija u rudnicima uglja. Do toga dovodi povećano zatezanje trake u transporterima sa trakom srednje dužine, pri čemu se ograničava uleganje trake između valjaka, koje je manje od 1%. Veća ušteda energije se dobija usled korišćenja motora kojima upravljaju frekventni konvertori – pokazano je kroz poređenje transportera sa trakom iz rudnika uglja Piast i transportera sa trakom iz rudnika uglja Jankovice. Produžen vek trajanja trake i drugih delova transportera, koji proističe iz pokretanja sa zadrškom, kočenja sa zadrškom, promena brzine trake, naročito dobijena ravnomerna raspodela opterećenja na pojedinačne pogone na mestu raspodele prema Ojlerovom zakonu, igraju odlučuju ulogu u ovom slučaju.

U klasičnim projektnim rešenjima transportera sa trakom, izvestan uticaj na uštedu energije imaju nepotpuna upotreba nominalne površine poprečnog preseka materijala koji se prenosi na traci, relativno malo unutrašnje trenje iskopine uglja a takođe i nagib bočnih valjaka od 30° ili 35°. Varijabilni protok materijala koji se stavlja na traku i nekorektna konstrukcija stanica za belt and incorrect construction of the run-of-mine dumping stations from one conveyor to the other and also an excessive use of the centring deflection of side rollers in the sets of load-bearing and return rollers have a disadvantageous impact on energy-saving.

It should be emphasized that a majority of factors, having an impact on an improvement of energy-saving conditions of belt conveyors, is known. At their designing and constructing stages the theories and methods of mechatronics for a comprehensive approach to the subject-matter under discussion should be taken into account.

odlaganje iskopine sa jednog na drugi transporter, kao i prekomerna upotreba otklona centriranja bočnih valjaka u nosećim i povratnim valjcima imaju nepovoljan uticaj na uštedu energije.

Treba naglasiti da je poznata većina faktora koji imaju uticaja na poboljšanje uslova transportera sa trakom u pogledu uštede energije. U fazi njihovog projektovanja i konstruisanja, trebalo bi uzeti u obzir teorije i metode mehatronike u cilju obuhvatnijeg pristupa ovoj problematici.

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