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

UDC:622.625.5:622.647

INCLINED BELT CONVEYORS FOR UNDERGROUND MINING APPLICATIONS

KOSI TRAKASTI TRANSPORTERI U PODZEMNOJ EKSPOLATACIJI

Jerzy ANTONIAK
Silesian Technical University,
44 -100 Gliwice, Akademicka 2, Poland

Abstract: *The paper deals with present-day technical solutions of inclined belt conveyor as implemented into Polish hard coal mines. The curved belt conveyor characterised by 2000 t/h capacity, a length of 1080 m and an inclination of almost 10°, that has found application as the first conveyor of this type in Europe belongs to the conveyors under consideration. Further development of inclined belt conveyors reaching the capacity of 3500 t/h and the length of more than 1 km is expected to take place in the nearest. Concepts relating to the technical solution of this problem have been briefly presented in the paper.*

Key words: *mining inclined belt conveyors, heavy duty, proposed technical solutions*

Apstrakt: *U radu su prikazana savremena tehnička rešenja za primenu kosih trakastih transportera u rudnicima kamenog uglja u Poljskoj. Prvenstveno se razmatra krivolinijski trakasti transporter čiji kapacitet iznosi 2000 t/h, dužina 1080 m i nagib oko 10°. Pomenuti transporter je prvi transporter ovog tipa koji se primenjuje u Evropi. Dalji razvoj kosih trakasti transportera koji dostižu kapacitet od 3500 t/h, a dugački su preko 1 km, očekuje se u veoma bliskoj budućnosti. U ovom radu daje se kratak prikaz osnovnih tehničkih rešenja koja se elaboriraju u cilju rešavanja ove problematike.*

Ključne reči: *kosi trakasti transporteri u rudarstvu, visoka produktivnost, predložena tehnička rešenja*

1. INTRODUCTION

From the history of underground coal mining it appears that transportation of the extracted material was kept in the background of the development of the technical equipment of coal faces and it did net pose any major problems till introducing of highly productive faces. Low-power and short belt conveyors served for transport purposes in mining districts. The main underground transport was effected by means of underground railway systems and skip winding plants were used for extracted material winding. In view of continuous increase in the output obtained on longwall faces and considering the existing economic conditions, the development of heavy-duty, efficient, reliable and serv

1. UVOD

U istoriji podzemne eksploatacije razvoj opreme za transport otkopanog materijala je bio u drugom planu u poređenju sa ostalom opremom na otkopnom čelu. Prvi problemi su se pojavili tek sa povećanjem produktivnosti. U podzemnoj eksploataciji koristili su se samo kratki transporteri malog kapaciteta, dok je šinski transport bio dominantan, a izvoz otkopanog materijala se obavljao skipom. Imajući u vidu kontinuirano povećanje kapaciteta na širokim čelima i, s obzirom na postojeću ekonomsku situaciju, razvoj visoko produktivnog, efikasnog, pouzdanog i dugotrajnog sistema trakastih transportera postaje veoma značajan. S obzirom na njihove brojne prednosti

ice-free belt conveying systems becomes of great importance. Owing to their numerous advantages the belt conveyors superseded the low-efficient and inflexible underground railway systems as well as shaft hoists, wherever it was possible.

2. ADVANTAGES OF TRANSPORTATION OF THE EXTRACTED MATERIAL ON INCLINES

In order to make full use of the existing infrastructure of shaft hoists (without shaft sinking) it is necessary to transport the extracted material downward or upward the incline. Inclines ranging from 10 to 16° are found most often. Transportation of the extracted material downward the incline takes place under energy recovery due to the application of current frequency converters for controlling of induction squirrel-cage motors, as it is the case at the Ziemowit and Halemba coal mine. However, transportation by means of inclined belt conveyors is predominant. Technical data relating to inclined belt conveyors are presented in the table 1.

Two of the presented conveyors are used to transport the extracted material from underground workings to the surface. They are in operation at the Janina coal mine. Each of the conveyors characterized in the table 1 is equipped with a soft starting system, two couplings – a flexible coupling and a rigid one of the Stouve type – a toothed gear, a hydraulic disk brake and with an anti-return device (backstop).

The fact that belt conveying with rising conveyor routes finds wider and wider application results from the following factors: increase of the concentration of extraction and formation of one-level mines leading to an increase in the economic effectiveness of mining of useful minerals, environment protection, continuous uniform system of transportation of the extracted material accompanied by simultaneous simplification of the conveying ways, enhanced safety, high reliability of particular con veyors, quick repayment of the incurred investment outlays (about 2 to 3 years), work comfort, easy automation of the transport system, possibility of negotiation of spatial curvatures as well as rendering the lower working levels accessible so that modernization of hoisting plants is not necessary. Wher ever the extracted material is transported from a face directly to the surface it is important that a serious and long standing customer of coal (e.g. power station) is located in the nearness of a coal mine.

The latest developments in the field of designing of modern high - power drives and of conveyor belts

trakasti transporteri su u uslovima podzemne eksploatacije potisnuli, gde god je to moguće, manje efikasni i nefleksibilni sistem šinskog transporta i izvoz oknom.

2. PREDNOSTI KOSOG TRANSPORTA OTKOPANOG MATERIJALA

U cilju što potpunijeg iskorišćenja postojeće infrastrukture za izvoz oknom (bez dubljenja okna) neophodno je, obezbediti transport otkopanog materijala uz i niz uskop. Najčešći nagib uskopa kreće se od 10 do 16°. Transport otkopanog materijala niz uskop, praktično, predstavlja uštedu energije, s obzirom na upotrebu konvertora strujne frekvence za kontrolu indukcije veveričasto-kaveznih motora, kao što je slučaj u rudnicima uglja Ziemovit i Halemba. Transport kosim trakastim transporterima je dominantan oblik transporta. Tehnički podaci o kosim trakastim transporterima prikazani su na tabeli 1.

Dva prikazana transportera koriste se za transport otkopanog materijala sa podzemnih otkopa na površinu. Ovi transporteri rade u rudniku uglja Janina. Svaki od transportera prikazanih na tabeli 1 opremljen je sistemom za bestrzajno startovanje, dva kvačila - jedno fleksibilno i jedno kruto kvačilo, tipa Stouv - jedan prenosnik sa zupčanicima, jedna hidraulička kočnica i uređaj za zaustavljanje povratnog hoda (ograničavač hoda kotve).

Činjenica da trakasti transporteri sa uzlaznim trasama imaju sve širu primenu proizilazi iz sledećih faktora: povećan kapacitet otkopavanja i organizovanje otkopavanja u jednom horizontu, bolji ekonomski efekti u ekspolataciji korisnih mineralnih sirovina, zaštita životne sredine, kontinuirani transport otkopanog materijala i pojednostavljivanje transportnih metoda, poboljšana bezbednost, visok stepen pouzdanosti pojedinih transportera, kratak rok otplate uloženih sredstava (od 2 do 3 godine), konforan rad, jednostavna automatizacija transportnog sistema, mogućnost savladavanja velikih krivina, lakši pristup donjim otkopnim horizontima, tako da nije potrebno vršiti modernizaciju izvoznog postrojenja. U slučaju da se transport otkopanog materijala vrši direktno sa otkopa na površinu, važno je da se veliki i dugoročni potrošač (napr. elektrana) nalazi u blizini rudnika uglja.

Napredak u oblasti projektovanja savremenih pogona velikog kapaciteta i visoko otpornih i

characterized by high strength and fire-resistance have brought about an increased interest in the belt conveying systems with rising conveyor routes.

nezapaljivih transportnih traka prouzrokovali su veliko interesovanje za trakaste transportere kao metode transporta na uzlaznim transportnim trasama.

Table 1 Characteristics of mining inclined belt conveyors
Tabela 1 Karakteristike kosih trakastih transportera u rudarstvu

Characteristic quantities	Hard coal mine					
	Piast	Krupi ski	Janina RII	Janina RI	Bolesław miały	Jankowice
Type of material conveyed	run-of-mine coal (hard coal + barren rock)					
Nominal carrying capacity, t/h	1000	950	800	1000	1200	2000
Conveyor length, m	560	760	980	1430	1313	1080
Elevating height, m	+87,6	+209	+237	+306	+205	+165
Conveying angle, degrees	9	16	14	12°30'	9	9°50'
Radius of curvature, m	-	-	-	-	-	600
Belt speed, m/s	3,15	2,0	0,6÷3,15	0,5÷3,15	0,2÷3,15	0,8÷3,15
Belt width, m	1,2	1,2	1,2	1,2	1,2	1,4
Drive power, kW	2x1x250+1R	4x250	3x1x315	4x1x315	4x250	4x1x355
Belt type	GTP* 1600/4/2	GTP ST 3150X	GTP ST 1600X	GTP PWG 2500/1	FRSR** 15000	GTP ST 3150
Distinguishing features	fluid couplings 562 TVVSC Voith-Turbo		voltage frequency converters made by ABB, Industry			current frequency converters made by Carboauto-matyka (Poland)

* *GTP – belt made by FTT Stomil Wolbrom (Poland)*
** *FRSR belt made by Fenner (Great Britain)*

Novel solutions introduced into domestic inclined belt conveyors consist in the application of compact small – sized multidrum drives which make it possible to use motors with the total power of more than 1 MW for driving of a conveyor in underground operations.

Novina u oblasti kosih trakastih transportera u domaćim uslovima odnosi se na primenu malih, kompaktnih pogona sa više bubnjeva, što omogućava upotrebu motora ukupne snage od preko 1 MW za pogon transportera u podzemnoj eksploataciji.

The curved belt conveyor (figure 1) as installed in the Jankowice coal mine constitutes the most noticeable achievements as regards the inclined belt conveyors that have been constructed so far.

Krivolinijski trakasti transporter (slika 1), koji je u upotrebi u rudniku uglja Jankovice predstavlja do sad najznačajnije dostignuće u oblasti konstruisanja kosih trakastih transportera.

This conveyor is characterized by the highest ever installed power of drives, by high carrying capacity, current frequency converters of the PPC-2/3 type suitable for 500 kW power and 1000 V voltage, that have been introduced for the first time, as well as by the fire-resistant belt designed as GTP ST 3150 and furnished with a protective interlayer.

Odlike ovog transportera su najveća do sada instalirana snaga pogona, velika nosivost, konvertori strujne frekvence tipa PPC-2/3 koji je pogodan za snagu od 500 kW i napon od 1000 V koji su ovde po prvi put primenjeni. Trake su nezapaljive, konstruisane kao GTP ST 3150 i snabdevene zaštitnim međuslojem.

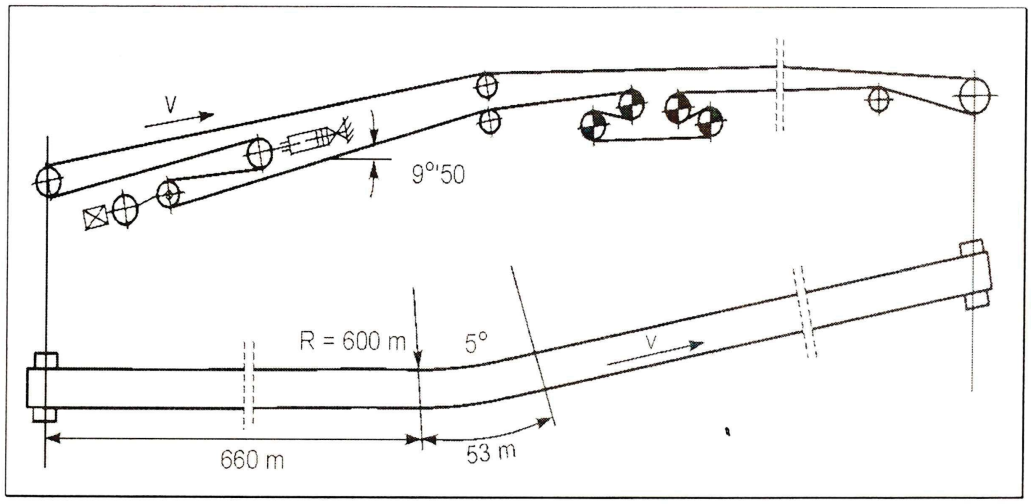

Figure 1 Curvilinear inclined belt conveyor at Jankowice hard coal mine
Slika 1 Krivolinijski kosi trakasti transporter u rudniku kamenog uglja Jankovice

High-power large-sized single drum drives are most often in use in case of belt conveyors transporting the extracted material to the surface. The drive power of the conveyor operated at the Selby mine (Great Britain) amounts to 2x5050 kW and at of the Prosper mine (Germany) conveyor is of 2x3100 kW. This conveyor is driven with two asynchronous motors controlled by current frequency converters. As a result, it was possible to connect the motors directly to a driving drum when omitting the toothed gears. A two-drum drive (2x2x500 kW) equipped with a full controlled fluid coupling as applied in the inclined belt conveyor route being in operation at the Ensdorf mine (Germany) proves to be more cost effective. Large overall dimensions of drives of this type and gassy character of mines are what hinders their application in underground workings.

3. MODERN DRIVES AND BELTS FOR MINING INCLINED BELT CONVEYORS

The application of multidrum drives in underground working of mines brings about the following advantages: possibility of using of interchangeable driving units and of motors with maximum permissible power considering a control system, situation of a discharge point of the extracted material at a greater distance from drives, reduction of the excavation in the vicinity of drives (the drives are situated on one side of a conveyor), reduction of the foundation work, concentration of the accompanying facilities and equipment such as: travelling cranes for assembly purposes, electric power substations, belt cleaning devices, brakes, mechanical back-stop, equipment for monitoring and

Pogoni velike snage i gabarita, sa jednim bubnjem se u većini slučajeva koriste za transportere koji prevoze otkopani materijal do površine. Pogonska snaga transportera koji je u radu u rudniku Selbi (velika Britanija) iznosi 2x5050 kW, a u rudniku Prosper (Nemačka) iznosi 2x3100 kW. Ovaj transporter pokreću dva asinhrona motora koji se regulišu pomoću konvertora strujne frekvence. Zahvaljujući tome, moguće je priključiti motore direktno na pogonski bubanj u slučaju kada se izostavlaju prenosnici sa zupčanicima. Pokazalo se da je pogon sa dva bubnja (2x2x500) sa potpunom regulacijom hidrauličkog kvačila koji je primenjen u transportu kosog trakastog transportera u rudniku Ensdorf (Nemačka) znatno ekonomičniji. Veliki gabariti pogona ovog tipa i povećana koncentracija gasa, karakteristična za rudnike sa podzemnom eksploatacijom, donekle predstavljaju prepreku za njihovo korišćenje.

3. SAVREMENI TIPOVI POGONA I TRAKA ZA KOSE TRAKASTE TRANSPORTERE U RUDARSTVU

Primena pogona sa više bubnjeva u podzemnoj eksploataciji ima sledeće prednosti: mogućnost primene izmenjljivih pogona i motora maksimalno dozvoljene snage, uzimajući u obzir sistem kontrole, zatim, da se tačka istovara otkopanog materijala nalazi na većoj udaljenosti od pogona, smanjeni obim otkopavanja u blizini pogona (pogoni su smešteni sa jedne strane transportera), manji obim radova na temeljima, lociranje na jednom mestu prateće opreme i uređaja, kao što su: pokretne dizalice za montažu, podstanice za električnu energiju, uređaji za čišćenje trake, kočnice, mehanički uređaji za zaustavljanje

controlling the conveyor operation, water coolers etc. in one place.

The modern multi-drum drives of mining inclined belt conveyors should meet the following requirements:

- compensation of loads between the drives is to be assured during start-up and steady-state running of the conveyor,
- loadless starting of motors or a very soft increase of starting torque from 0 to values at which actuation of the conveyor takes place,
- possibility of regulation of the course of start-up and of its parameters with the coefficient of starting being kept less or equal to 1.2,
- start-up a conveyor should be conditioned by the state its loading,
- protection against reverse motion of a belt and correct braking of the conveyor,
- small height and small width in direction crosswise to the belt axis,
- possibility of the operation at different speeds of the belt running,
- easy and simple service, compact design,
- proper furnishing with sensors which make it possible to control the drives and to effect the connection with master control system.

In view of the mechanical properties of multi-drum drives determined by the frictional contact, and especially by the elastic slip of a belt an each successive driving drum, these requirements are rather unlikely to be met by a simple drive incorporating an asynchronous motor, a flexible coupling and a multi-stage gear. Therefore, special drive systems, in which high-tech design finds application, are introduced into multi-drum drives.

These drives cover:

- constant filling fluid couplings of the 526 TVVSC type (figure 2) with an additional starting chamber made by Voith-Turbo Company,
- drives with water flow-controlled turbo coupling of the DTP type made by Voith-Turbo Company,
- drives with a planetary gear of the CST system made by the Dodge Company,
- drives motors with being controlled by means of voltage or current frequency converters (figure 3).

povratnog hoda, oprema za monitoring i kontrolu rada tračnog transportera, hladnjaci za vodu itd.

Savremeni pogoni sa više bubnjeva za kose trakaste transportere koji se koriste u rudarstvu treba da zadovolje sledeće zahteve:

- treba obezbediti ravnotežu tereta između pogona u toku startovanja i stabilnog rada transportera,
- lako, bestrzajno startovanje motora, ili veoma stabilno i postepeno povećanje startnog obrtnog momenta od 0 do vrednosti na kojoj dolazi do pokretanja transportera,
- mogućnost regulacije toka startovanja i odnosnih parametara sa koeficijentom startovanja koji mora biti manji ili jednak 1.2,
- startovanje transportera mora biti uslovljeno njegovim opterećenjem,
- zaštita od povratnog hoda trake i ispravno kočenje transportera,
- mala visina i širina u pravcu koji je poprečan u odnosu na osu trake,
- mogućnost rada pri različitim brzinama kretanja trake,
- lako i jednostavno servisiranje i održavanje, kompaktna konstrukcija,
- odgovarajuća opremljenost senzorima koji omogućavaju kontrolu pogona i obezbeđuju povezivanje sa centralnim kontrolnim sistemom.

Imajući u vidu mehanička svojstva pogona sa više bubnjeva koji su uslovljeni frikcionim kontaktom, posebno elastičnim proklizavanjem trake na svakom sledećem pogonskom bubnju, pomenute zahteve je veoma teško ispuniti jednostavnom ugradnjom asinhronog motora, fleksibilnog kvačila i više - stepenog zupčanika. Prema tome, radi postizanja pomenutog cilja neophodno je u pogone sa više bubnjeva ugraditi specijalni pogonski sistem, visoke tehnologije.

Ovi pogoni pokrivaju:

- kvačila sa konstantnim prilivom tečnosti, tipa 526 TVVSC (slika 2) sa dodatnom komorom za startovanje - proizvođač Voit-Turbo Kompanija,
- pogon sa turbo kvačilom i regulacijom protoka vode tipa, DTP – proizvođač Voit-Turbo Kompanija,
- pogon sa reduktorom CST sistema – proizvođač Kompanija Dodž,
- motor pogona koji se regulišu pomoću konvertora naponske ili strujne frekvence (slika 3).

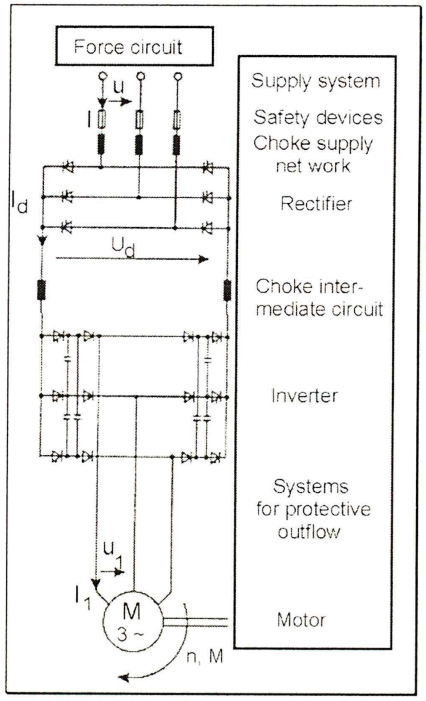

Figure 2

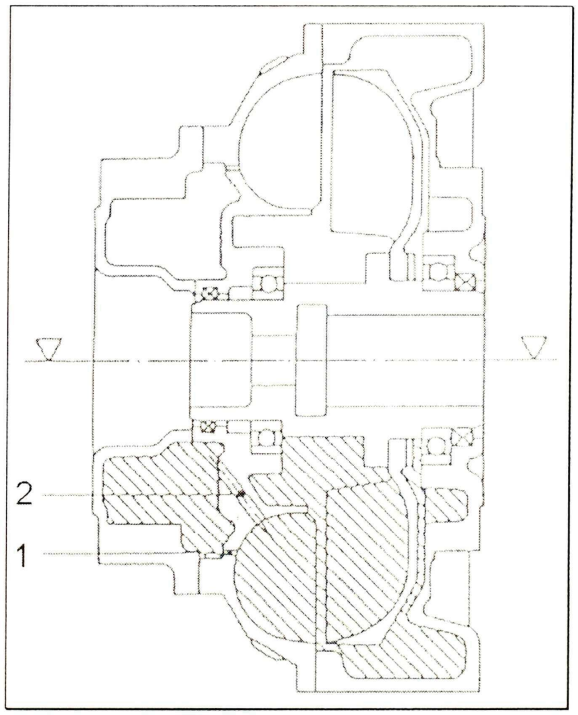

Figure 3

Figure 2 Hydrodynamic coupling with constant filling and with two retardation chamber type TVVS made by Voith Germany; 1 – nozzle, 2 – hole for return flow
Slika 2 Hidrodinamičko kvačilo sa konstantnim prilivom tečnosti sa dve kočione komore, tipa TVVS proizvođač Voit Nemačka; 1 – dizna, 2 – otvor za povratni tok

Figure 3 Current frequency converter for 500 kW active power type PPC-2/3 made by Carboautomatyka Poland
Slika 3 Konvertor strujne frekvence za radni kapacitet od 500 kW, tip PPC-2/3 proizvođač Karboautomatika, Poljska

For underground applications fluid couplings are robust construction supplied with a steel outer casing and akwafil. Water flow-controlled turbo coupling of the DTP type are characterized by a completely loadless start-up of synchronous motors, which can be carried out with motors being switched on in any order whereas rotors of the couplings are unfilled. The moment the start-up of motors has been accomplished, couplings are being gradually filled and acceleration of the conveyor running takes place. Water serving as working medium is fed to a coupling by proportioning effected through closing and opening of a filling and discharging valve. A master control system provides for the obtainment of preset values of the torque at any state of the conveyor running. Thus, the same torque is preset to each of the driving drums and a slip of the coupling allows the rotational speed of each successive drum to be adjusted to the speed of the first drum when taking an elastic slip of the belt into account. It is possible to regulate the belt speed owing to partial filling of the coupling accompanied by a greater slip. Any

Robusna konstrukcija hidrauličkih kvačila, njihovo čelično kućište i odgovarajuća izolacija čine ih veoma podesnim za rad u uslovima podzemne ekspoatacije. Turbo kvačilo sa kontrolisanim protokom vode, tipa DTP je poznato po lakom, bestrzajnom pokretanju sinhronih motora, koje se može obaviti u bilo kom redosledu uključivanja motora, bez obzira na to da li su motori kvačila prazni ili ne. Motori su startovani, kvačila se postepeno pune i kretanje transportera se ubrzava. Kvačilo se napaja vodom koja služi kao radni fluid, a dozira se otvaranjem i zatvaranjem napajajućeg i ispusnog ventila. Centralni kontrolni sistem obezbeđuje održavanje unapred ustanovljenih vrednosti obrtnog momenta u bilo kom trenutku rada transportera. Pogonski bubnjevi se podešavaju na isti obrtni momenat, a poseban klin na kvačilu omogućava usklađivanje rotacione brzine svakog bubnja sa prvim bubnjem, kada se uzme u obzir elastično proklizavanje trake. Brzinu trake moguće je regulisati zahvaljujući delimičnom napajanju kvačila. Moguće je postići bilo koju brzinu trake u opsegu od 100 do 20% nominalne brzine. Pomoću

speed of the belt contained within the range between 100 and 20% of the nominal speed is obtainable. In case of these couplings the following quantities can be regulated: revolutions of an input shaft, drive power and starting time. Drives, in which couplings of this type are incorporated, are applicable for curved inclined conveyors as well as for conveyors characterized by large undulations and for intermediate drum drives, if sensors measuring the belt tension situated in the drive area.

In case of drives of CST type the first drum is operated in a rigid system and the successive drums run with a slip. In each drive a constant torque is preset by means of a control system that regulates holding down of disks of a wet clutch.

In drives provided with frequency converters the speed control in a drive system is affected by changing the frequency of voltage supplied to asynchronous motors. The frequency is being changed in an infinitely variable way and thus, a smooth control of the drive system takes place. A constant torque of motor (of motors) covering the whole range of frequency variation is a result of maintaining of a constant value of the ratio of supply voltage to voltage frequency: U/f = const. As a rule the speed regulation takes place without loss of energy. This speed can be adjusted to the required loading of belt with material transported. Control systems using the voltage frequency converters (transistors) and those using current frequency converters (thyristors) differ one from another.

The greatest possibilities of regulation are offered by a drive incorporating motor controlled with voltage frequency converters. In respect of investment outlays the drives are classified in the following order: a drive with fluid couplings is the most cost-effective one, a drive with a transmission gear of the CST system is more expensive and a drive with frequency converters involves the highest costs. Apart from high-power drives the fire resistant and high strength belts are of essential importance for the construction of inclined belt conveyors. At present, belts with steel cords and belts with textile cords the so-called solid woven or monoply belts. Technical data relating to these belts are presented in table 2 and 3.

From the tables it appears that up to the strength of 3150 N/mm the solid woven belts are by a half lighter than belts with steel cords of the same strength. Only in case of the strength of above 4000 N/mm there is no alternative for belts with steel cords.

ovih kvačila može se postići regulacija sledećih vrednosti: broj obrtaja ulaznih vratila, pogonska snaga i vreme startovanja. Pogoni sa ovim tipom kvačila mogu se koristiti za krivolinijske kose trakaste transportere, za transportere koji imaju talasastu trasu i za pogone među-bubnjeva, s tim da senzori koji mere napon trake moraju biti postavljeni u blizini pogona.

Kod pogona tipa CST prvi bubanj radi u krutom sistemu, a svaki sledeći ima klizni hod. Obrtni momenat je konstantan i unapred podešen za svaki pogon pomoću kontrolnog sistema koji reguliše blokiranje diska kvačila.

Kod pogona koji imaju konvertore frekvence, promena naponske frekvence kojom se napaja asinhroni motor, utiče na kontrolu brzine, pogonskog sistema. Promena frekvence se odvija na beskonačno mnogo načina, pa prema tome, mora se uspostaviti regulacija ravnomernog rada pogonskog sistema. Konstantan obrtni momenat motora koji pokriva veliki opseg u promeni frekvence je posledica održavanja konstantne vrednosti odnosa između napona i naponske frekvence: U/f = const. Po pravilu, regulacija brzine odvija se bez gubitka energije. Ova brzina može se podešavati u zavisnosti od toga koliko je traka opterećena materijalom koji se transportuje. Kontrolni sistemi koji koriste konvertore naponske frekvence (tranzistori) i oni koji koriste konvertore strujne frekvence (tiristori) razlikuju se jedan od drugog.

Najveću mogućnost regulacije nudi pogon u koji je ugrađen motor sa konvertorima naponske frekvence. U zavisnosti od potrebnih ulaganja pogoni se mogu svrstati na sledeći način: pogon sa hidrauličkim kvačilom je najekonomičniji, pogon sa transmisijom, tipa CST je skuplji, dok pogon sa konvertorima frekvence zahteva najveća ulaganja. Kod kosih trakastihh trensportera, osim pogona visokog kapaciteta, veoma su važne i trake koje moraju biti visokootporne i nezapaljive. U današnje vreme koriste se trake sa čeličnim i tekstilnim uloškima, takozvane čvrsto tkane ili monopol trake. Tehnički podaci koji se odnose na ove trake prikazani su u tabelama 2 i 3.

Iz navedenih tabela proizilazi da su čvrsto tkane trake čija čvrstoća dostiže vrednost do 3150 N/mm upola lakše od traka sa čeličnim uloškom iste čvrstoće. Samo kod čvrstoće preko 4000 N/mm trake sa čeličnim uloščima nemaju alternativu.

Table 2. Textile-carcass belts in self-extinguishing version
Tabela 2. Trake sa tekstilnim uloščima - nezapaljive

Specification	Type of conveyor belts								
	one-carcass (solid woven)						2 car-cass	4 -carcass	
	1600	1800	2000	2500	2625	3150	1600	1600	2000
FTT Stomil Wolbrom S.A. GTP PWG and GTP Belt thickness, mm Thickness of rubber covers, mm Approx. belt weight, kg/m^2				24 5+3 32				21/24 4+3/7+4 29/35	
Phoenix AG Belt thickness, mm Thickness of rubber covers, mm Approx. belt weight, kg/m^2	16 3+3 24		20 3,5+3,5 31	22 4+4 33,5		26,5 6+3 36	16 4+2 21		
Fenner Conveyor Belting belts FR Belt thickness, mm Thickness of running covers, mm Thickness of carrying covers, mm Thickness of cord, mm Nominal belt weight*, kg/m^2	14 10 14,2	15 1÷3 1÷3 11 14,6	17 1÷3 1÷3 12 16,2		18 1÷3 1÷3 13 17,4				

**The given values of the belt weight refer to belts with covers made from PVC 1 mm thick. For each subsequent 1 mm of thickness it is necessary to add 1.3 kg/m^2.*

**Date vrednosti za težinu trake odnose se na trake sa PVC oblogama, debljine 1 mm. Za svaki sledeći 1 mm debljine treba dodati 1.3 kg/m^2.*

Table 3 Self-extinguishing belts with steel cords
Tabela 3 Nezapaljive trake sa čeličnim uloščima

Specification	Type of conveyor belts						
	1600	2000	2500	3150	3500	4000	4500
FTT Stomil Wolbrom S.A. GTP ST/X Cord diameter, mm Thickness of rubber covers, mm Total thickness of belt, mm Approximate weight, kg/m^2	6,0/4,6 10+6 26 41	6,0/5,0 10+8 24 47	7,6/5,6 12+8 28 54	8,5/6,0 12+10 30 58		9,5/8,0 14+10 33 64	
Phoenix Conveyor Belt Technology Core thickness, mm Thickness of rubber covers with transverse textile reinforcement (T)*, mm Total thickness of belt, mm Approximate weight, kg/m^2	6 10T+6T 22 40,5	6 10T+8T 24 45	7 10T+8T 25 49	8 10T+8T 26 52	9 10T+8T 27 55	9 12T+8T 29 60	10 12T+8T 30 63

**weight of 1 mm of the rubber cover thickness is of 1,5 kg/m^2,*
*** belt weight can indicate deviations +1,5/–0,8 kg/m^2*

**težina 1 mm debljine gumene obloge iznosi 1,5 kg/m^2,*
*** težina trake može ukazati na odstupanja +1,5/–0,8 kg/m^2*

Of course, each type of the belts has its advantages and disadvantages; the selection of a given kind and type of the belt proves to be a complicated problem and needs a detailed analysis.

Naravno, svaki tip trake ima svoje prednosti i nedostatke, pa se, shodno tome, pokazalo da je izbor određenog tipa i vrste trake veoma složen problem koji zahteva detaljnu analizu.

4. FURTHER DEVELOPMENT OF INCLINED BELT CONVEYORS

A decision is just to be taken in one of coal mines as regards the transportation of the extracted material from four longwall faces from the 1000 m level to the 830 m level. It is expected that the output coming from one face will amount to about 1000 t/h. With a factor of non-uniformity of 0.75 this output brings about the required carrying capacity of a rising belt conveyor of about 3000 t/h.

The bulk density of the material extracted at this coal mine is of about 1.4 t/m^3 because of a great amount of barren rock. On the average, a gradient of the incline is of 9.5° what in case of rising height of 170 m results in a con veyor length of 1030 m.

Considering the required capacity it is necessary to assume the application of a belt of 1.4 m in width when supported by idler sets of ϕ133 mm with a troughing angle of side idlers being 35°.

In order to increase the belt strength in has been assumed that the conveying speed should be 4.0 m/s. Nevertheless, a unit load of conveyed material on the belt amounts to 215.3 kg/m. Having in view such a load it has been designed that supporting idlers will be spaced at 1.2 m and bottom idlers at 2.4 m. Several versions of the technical equipment of the incline and namely versions of furnishing the incline with one, two and three belt conveyors have been taken into consideration.

A belt of the ST 4000 type with specific weight of 85 kg/m and thickness of 29 mm provided with covers 12T and 8T (as made by the Phoenix company) or a similar belt GTP ST 4000 as made by the FTT Stomil Wolbrom S.A. company has been assumed suitable for the one conveyor version. The calculations have been made under utilization of the standard DIN 22101. The obtained diagram illustrating the belt tension is shown in figure 4.

Technical characteristics of the versions under consideration, based on the calculations carried out, are presented in the table 4.

From the experiment performed at the Jankowice coal mine it has appeared that a reserve on the drive power is needed because of periodical overloading of the conveyor by the extracted material containing a large portion of barren rock. Therefore, five driving units with power of 500 kW each have been taken into account for the first version of the equipment. Thus, the total power amounts to 5 x 500 kW = 2500 kW providing for a consider-

4. DALJI RAZVOJ KOSIH TRAKASTIH TRANSPORTERA

U jednom rudniku uglja, upravo, treba da se odabere način transporta otkopanog materijala sa četiri široka čela i to sa kote 1000 m na kotu 830 m. Očekuje se da će proizvodnja na jednom širokom čelu dostići vrednost od 1000 t/h. Uzimajući u obzir faktor neravnomernosti od 0.75, navedena proizvodnja će ostvariti potreban transportni kapacitet uzlaznih trakastihh transportera od oko 3000 t/h.

Zapreminska masa otkopanog materijala u ovom rudniku uglja iznosi oko 1.4 t/m^3 zbog velikog procenta jalovine. U proseku ugao nagiba iznosi 9.5°, što uz visinu uspona od 170 m daje dužinu transportera od 1030 m.

Uzimajući u obzir kapacitet koji je potrebno ostvariti predlaže se upotreba trake širine 1.4 m, koja se oslanja na noseće valjke od ϕ 133 mm, pri čemu ugao nagiba nosećiih valjaka iznosi 35°.

U cilju poboljšanja čvrstoće trake predlaže se da transportna brzina bude 4.0 m/s. Jedinično opterećenje transportovanog materijala na traku iznosi 215.3 kg/m. S obzirom na pomenuto opterećenje predviđeno je projektom da noseće rolne budu postavljene na razmaku od 1.2 m, a povratne rolne na 2.4 m. Uzeto je u razmatranje nekoliko verzija rešenja tehničke opreme kosog transporta i nekoliko varijantnih rešenja za postavljanje jednog, dva i tri tračna transportera.

Traka tipa ST 4000 specifične težine od 85 kg/m i debljine 29 mm sa oblogama 12T i 8T (kao što su trake proizvodnje kompanije Feniks) ili slična traka tipa GTP ST 4000 (kao trake proizvodnje kompanije FTT Stomil Volborm S.A) se uzimaju u obzir za rešenje sa jednim transporterom. Kalkulacije se baziraju na standardu DIN 22101. Dijagram koji ilustruje zatezanje trake prikazan je na slici 4.

Tehničke karakteristike razmatranog rešenja transporta izvedene na osnovu kalkulacija prikazane su u tabeli 4.

Na osnovu eksperimenta koji je sproveden u rudniku uglja Jankovice može se zaključiti da je neophodno obezbediti rezervni pogon, jer povremeno dolazi do preopterećenja transportera otkopanim materijalom sa povećanim sadržajem jalovine. Prema tome, u okviru prvog rešenja razmatra se korišćenje pet pogona snage od po 500 kW. Dakle, ukupna pogonska snaga iznosi 5x500 kW=2500 kW, što obezbeđuje značajan

able excess of power in the drives. The drive can be designed as a five-drum drive (figure 5) with 500 kW motors controlled by means current frequency converters PPC-2/3, as made by the Carboautomatyka S.A. company.

višak snage u pogonima. Pogon može biti konstruisan kao pogon sa pet bubnjeva (slika 5) sa motorima od po 500 kW koje kontrolišu konvertori strujne frekvence PPC-2/3, kao što proizvodi kompanija Karboautomatika D.D.

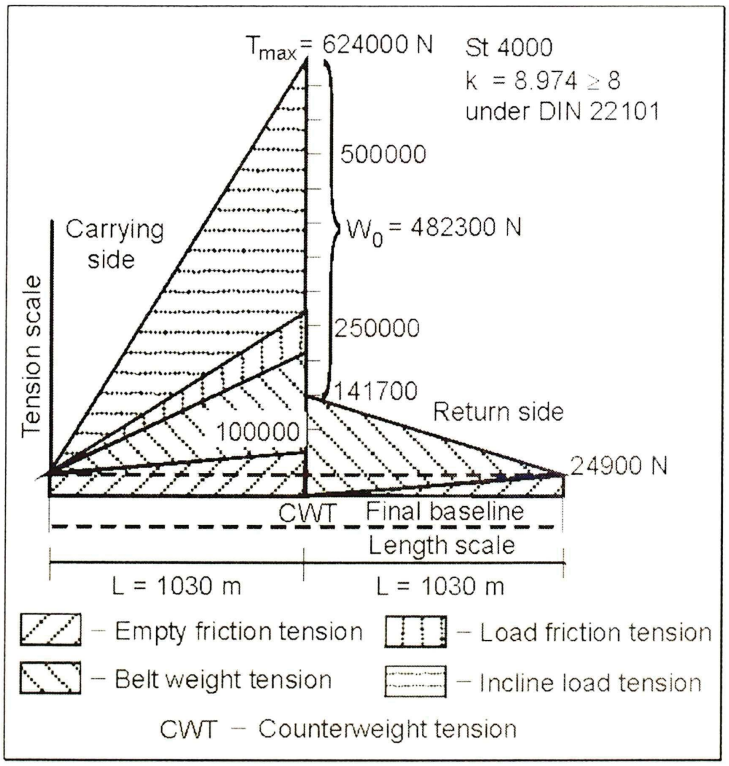

Figure 4 Diagram of the belt tensions of considered single inclined belt conveyor
Slika 4 Dijagram sila zatezanja trake u okviru razmatranog sistema sa jednim kosim trakastimm transporterom

Table 4 Technical parameters characteristic for the considered versions of the mechanical equipment of an incline used for transportation purposes
Tabela 4 Karakteristični tehnički parametri razmatranog rešenja mehaničke opreme

Design version of conveyor	Belt speed m/s	Belt type	Factor of belt safety	Drum diameter m	Power drives, kW				Number of driving drum	Special technical solution of drive
					calculated power	single drive power	total power	excess of power %		
One-conveyor version	4,0	ST 4000	8,97 >8	1,29	2145	500	2500	16,5	5	Current frequency converter PPC-2/3
Two-conveyor version	3,86	Mono-ply 2000	10,3 >10	1,28	2030	355	2130	5	3 x 2	Voith's fluid coupling
Three-conveyor version	3,86	Mono-ply 1600	12,5 >10	1,03	2030	355	2130	5	2 x 3	Voith's fluid coupling

When a belt of the 1600 N/mm type finds application, it is possible to increase the spacing of idler sets of the top strand from 1.2 to 1.5 m and those of the bottom strand from 2.4 to 3.0 m.

Kada se primenjuje traka tipa 1600 N/mm, moguće je povećati razmak nosećih valjaka kod gornjeg postroja sa 1.2 na 1.5 m, a kod donjeg postroja sa 2.4 na 3.0 m.

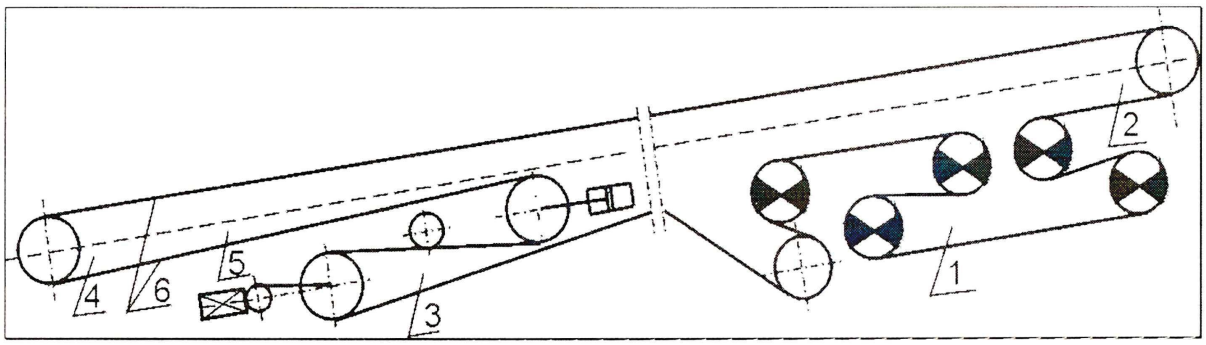

Figure 5 Preliminary project of the inclined belt conveyor of the 3500 t/h capacity equipped with five-drum drive of 5 x 500 kW=2500 kW power with motors controlled by current frequency converter of PPC-2/3 type;
1 – drive, 2 – extension arm, 3 – tensioning device, 4 – switch point, 5 – carrying construction, 6 – belt of the GTP ST 4000 type

Slika 5 Nacrt kosog tračnog transportera kapaciteta 3500 t/h, snabdeven pogonom sa pet bubnjeva snage 5x500=2500 kW, regulacija motora konvertorom strujne frekvence tipa PPC-2/3;
1 - pogon, 2 - produžni krak, 3 - zatezni uređaj, 4 - presipno mesto, 5 – noseća konstrukcija, 6 - traka tipa GTP ST

The assumption has been made that all the belt conveyors under consideration will be equipped with driving units situated on one side of the conveyor only. In another case the arrangements of drives can be diversified. The disadvantage of versions with two or three conveyors consists in a greater number of transfer stations and in an increase of dust level as well as in that there is not any possibility of regulating the incline in places where drives are to be installed and to distribute the electric power installation, water system etc. what leads to a reduction of reliability of the series arrangement of belt conveyors.

The one-conveyor version seems to be the most advantageous of the versions under consideration. A very soft start-up and an infinitely variable control of the belt speed in the range from 0.5 to 4.0 m/s in the function of the flux of conveyor material: v/v_n / Q/Q_n are good points of this version. The speed control leads to reduction of the energy required for transportation of the extracted material. In case of a inclined belt conveyor (the first version) about 75% of the energy is consumed for elevating the carried material so the reduction of energy consumption can be only achieved through reducing the energy consumed when overcoming principal resistance of the conveyor (frictional resistance, resistance to wary motion of the belt and of the material carried).

From the diagram (figure 6) it is evident that when the average carrying capacity is of 70% of the nominal capacity Q_n and the belt speed becomes decreased

Dato rešenje podrazumeva da će svi trakasti transporteri koji se uzimaju u obzir biti opremljeni pogonskim uređajima koji su smešteni samo sa jedne trane transportera. U ostalim slučajevima raspored pogona može biti i drugačiji. Nedostatak rešenja sa dva ili tri transportera sastoji se u prevelikom broju pretovarnih stanica i povećanoj koncentraciji prašine, kao i u činjenici da ne postoji mogućnost da se savlada kosina na mestima gde treba postaviti pogonske stanice i sprovesti instalacije za električnu energiju, vodu itd., što dovodi do smanjene pouzdanosti sistema serijskog rasporeda trakastihh transportera.

Sistem sa jednim transporterom izgleda kao najpovoljniji među predloženim rešenjima. Dobre strane ovog rešenja su lagano, bestrzajno startovanje i promenljivost brzine u rasponu od 0.5 do 4.0 m/s u zavisnosti od protoka materijala koji se transportuje: $v/v_n/Q/Q_n$. Regulacija brzine omogućava smanjenu potrošnju energije potrebne za transport otkopanog materijala. Kod kosog transportera (prvo rešenje) oko 75% energije se troši za podizanje tereta, pa se potrošnja energije može jedino smanjiti kroz uštedu prilikom savladavanja osnovnog otpora transportera (otpor trenja, otpor prema usporenom hodu trake i materijala koji se transportuje).

Sa dijagrama (slika 6) jasno se vidi da, u slučaju da je prosečna nosivost 70% od nominalnog kapacitet Q_n, a brzina trake se smanji za 70% od

to 70% of the nominal speed, the energy saving of about 4% is obtained.

The practice indicates that the savings of the energy are bigger and lead to diminishing of the operating costs. Conveyors running at a revision speed and at a speed adapted for manriding provide for additional advantages. Such a solution is optimal for heavy-duty inclined belt conveyors.

nominalne vrednosti, postićiće se ušteda energije od oko 4%.

Praksa pokazuje da ušteda energije može biti i veća što dovodi do smanjenja operativnih troškova. Transporteri čija je brzina izmenjena ili prilagođena za prevoz ljudi imaju dodatne prednosti. Takvo rešenje je optimalno za visoko-kapacitativne kose tračne transportere.

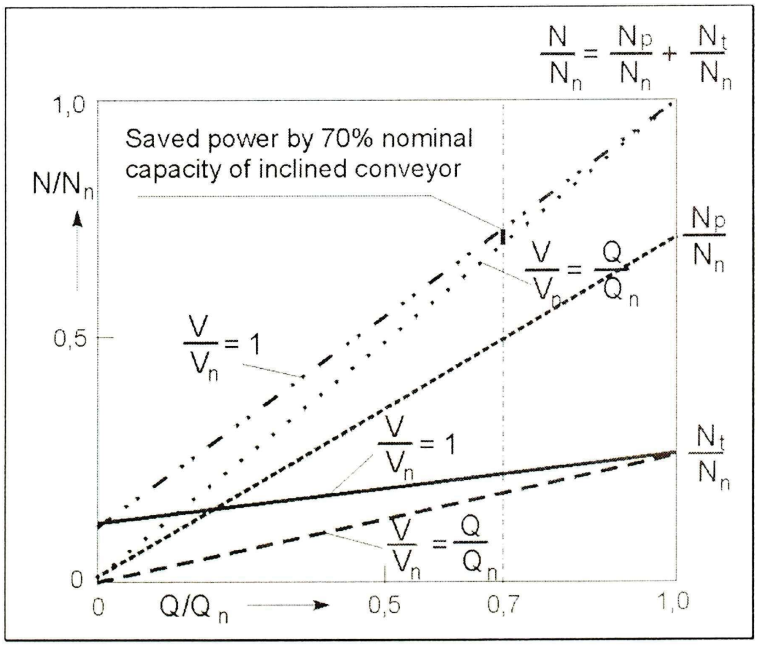

Figure 6 Diagram showing quantity of the saved power by 70% nominal capacity of inclined belt conveyor with motors controlled by current frequency converter;
Q – conveyor capacity, V – belt speed, N – active power order, index n – nominal value,
N_t, N_p. – power adequate for main resistances and hoisting

Slika 6 Dijagram koji pokazuje uštedu energije kroz 70% nominalnog kapaciteta kosog trakastog transportera čiji se motori regulišu konvertorom strujne frekvence;
Q – kapacitet transportera, V – brzina trake, N – red veličina stvarne snage,
index n – nominalna vrednost, N_t, N_p – adekvatna snaga za otpornost i dizanje

5. CONCLUSION

In view of the fact that coal reserves deposited on shallow levels become worked out, the coal mines start to extract deeper lying seams. Transportation of the extracted material by means of inclined belt conveyors proves to be the most cost-effective and the fastest method under these conditions. As the development of inclined belt conveyors proceeds and the experience in the field of their operation is gained, the requirements to be met by these conveyors are increased.

The paper presents an example of further development of conveyors of this type, which makes it possible to obtain the carrying capacity of 3500 t/h

5. ZAKLJUČAK

S obzirom na činjenicu da se rezerve uglja koje se nalaze u plićim delovima ležišta iscrpljuju, u rudnicima uglja počinju da se eksploatišu dublji slojevi. Pokazalo se da su kosi trakasti transporteri najekonomičniji i najbrži metod transporta otkopanog materijala. Napredak i nova iskustva koja se stiču u oblasti primene kosih trakastihh transportera povećavaju mogućnosti i performanse ovih transportera.

Članak prikazuje primer razvoja ovog tipa transportera, koji omogućava postizanje nosivosti od 3500 t/h i povećanje ukupne pogonske snage na 2.5 MW. Predloženo rešenje koje podrazumeva

and to enlarge the total power of drives up to 2.5 MW. The proposed solution covering a five-drum drive constitutes the further evolution of the concept of multidrum drives, which incorporate motors controlled by means of current frequency convert ers made by Carboautomatyka S.A. company. However, I am of opinion that an implementation of a five-drum drive must be preceded by precise measurements and tests on a four-drum drive so that any possible abnormalities of the operation of the five-drum can be prevented.

The proposed solution of the conveyor needs designing and introducing into the production of induction squirrel-cage motors of 500 kW in power and of 1000 V in voltage. It is also necessary to continue the improvement of a design of belts with steel cords of high strength and furnished with fire resistant protective carcasses. Moreover, there is a number of problems, which need solving, such as control and diagnostics of a conveyor, safety engineering and others.

pogon sa pet bubnjeva predstavlja osnov za dalji razvoj koncepcije koja predviđa pogon sa više bubnjeva. Regulacija motora obavlja se preko konvertora strujne frekvence čiji je proizvođač kompanija Karboautomatika. Međutim, smatram da pre uvođenja pogona sa pet bubnjeva treba sprovesti detaljna merenja i testove na postojećim pogonima sa četiri bubnja, kako bi se sprečile eventualne nepravilnosti.

Za potrebe ovog rešenja neophodno je konstruisati i proizvesti motor sa veveričastim kavezom, snage 500 kW i napona 1000 V. Takođe je veoma značajno da se i dalje razvija i usavršava proizvodnja traka sa čeličnim ulošcima velike čvrstoće koji su snabdeveni zaštitnim nezapaljivim slojem. Osim toga, postoji niz problema koje treba rešiti, kao što su dijagnostika i upravljanje transporterima, tehnička zaštita i drugo.

REFERENCES / LITERATURA

[1] *Antoniak J.*: Inclined mining belt conveyor with spatial curve. Proceedings of the sixteenth International Conference on "Material flow, machines and devices in industry". University of Belgrad, December 2000, Yugoslavia.

[2] *Antoniak J.*: Long belt conveyors with rising routs for mining applications. III International Conference on "Modern belt conveyors for underground coal mining". The Silesian Technical University – Szczyrk, September 1998.

[3] *Wuschek V.*: Neuartige Antriebslösung verringert Energie Aufwand bei der Kohleförderung. Energie und Automation, Heft 3/1987.