



## POSSIBILITIES FOR THE USE OF HIGH ANGLE CONVEYERS IN SMALL COAL MINES

### MOGUĆNOSTI PRIMENE VISOKONAGIBNIH TRANSPORTERA U MALIM RUDNICIMA UGLJA

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**Abstract:** In underground coal mines in Serbia one of the biggest problems is coal transportation. Big lengths of transportation, old equipment for transportation, numerous transportation units etc. demand decisions which should decrease costs, increase safety and reliability of transportation. Possibilities for the use of high angle conveyors systems are considered in this paper, because these conveyors can decrease and eliminate many problems during the coal transportation from coal face to surface.

**Key words:** underground coal mines, high angle conveyors systems

**Apstrakt:** U rudnicima uglja sa podzemnom eksploatacijom u Srbiji jedan od najvećih problema je transport uglja. Velike dužine transporta, zastarela oprema za transport, veliki broj transportnih jedinica i sl., zahtevaju rešenja koja će smanjiti troškove, povećati sigurnost i pouzdanost transporta. U ovom radu se razmatraju mogućnosti primene sistema sa visokonagibnim transporterima, koji mogu smanjiti i otkloniti veliki deo problema pri transportu uglja od radilišta do površine.

**Ključne reči:** podzemna eksploatacija uglja, visokonagibni transporteri

## 1 INTRODUCTION

In order to make the price of underground mined coal competitive on the market costs in all production stages must be reduced to a minimum. This particularly refers to haulage and hoisting having in view that in current mining existence of large haulage distance, large number of transfer points and a great variety of transport means and plants is characteristic. This problem becomes even more important when one has in view that collieries in Serbia fall into the category of small mines with annual outputs ranging from several tons to several hundred of thousands of tons.

## 1 UVOD

Da bi cena uglja, dobijena podzemnom eksploatacijom, bila konkurentna na tržištu, neophodno je da se u svim fazama proizvodnje troškovi svedu na minimum. To se naročito odnosi na transport i izvoz, jer je u sadašnjoj eksploataciji karakteristično da postoje velike dužine transportnih puteva, veliki broj presipnih mesta i značajna raznolikost transportnih sredstava i uređaja. Ovaj problem postaje još značajniji ako se ima u vidu da rudnici uglja u Srbiji spadaju u kategoriju malih rudnika sa godišnjom proizvodnjom od nekoliko desetina do nekoliko stotina hiljada tona.

Underground coal mines in Serbia can be ranged as mines with hard working conditions. Coal deposits are located at great depths, with complex structures and with limited possibilities for application of high productive mechanized equipment. Coal transport to the surface presents itself as an outstanding problem, since in most cases the application of hoisting system is financially irrational.

The objective of this paper is to indicate the possibilities of applying special belts conveyors with high-angle inclines for coal hoisting to the surface. Namely, it is not always rational to construct shafts with expensive hoist plants for low outputs and deposits intersected by faults. Likewise, use of classic belt conveyors requires long transport roads due to limited allowed route inclines. All this imposed the need to consider the application of high-angle conveyors capable of managing the necessary height balance.

## 2 APPLICATION OF THE HIGH ANGLE BELT CONVEYORS IN COLLIERIES

Basic problems occurring in Serbian collieries when haulage is in question may be classified into several groups, the most being a large number of transportation units, large haulage distances per ton of mined coal, low transport means efficiency rate, high equipment and haulage roads maintenance costs and the like.

Large haulage roads distances results as a consequences of stope distances from discharge plants on the surface. In order to shorten these distances possibilities for applying three types of special conveyors were considered: pipe conveyors; conveyors with pockets and corrugated edges (Flexowell) and conveyors with a pressure belt (sandwich conveyors).

Considering the possibility of using pipe conveyors and taking into account all advantages and shortcomings, it was concluded that currently application is unrealizable in small output collieries due to below reasons:

Rudnici uglja u Srbiji se svrstavaju u rudnike sa teškim uslovima rada. Ležišta uglja se nalaze na velikim dubinama sa složenim strukturama i ograničenim mogućnostima za primenu visokoproduktivne mehanizovane opreme. Transport uglja na površinu predstavlja takođe konstantan problem, a primena savremenih sistema izvoza je zbog nedostatka finansijskih sredstava nerealna.

Cilj ovog rada je da ukaže na mogućnosti primene specijalnih transporterera sa trakom za velike nagibe prilikom izvoženja uglja na površinu. Naime, za male proizvodnje i za ležišta ispresecana rasedima, nije uvek racionalno graditi okna sa skupim izvoznim postrojenjima. Takođe, primena klasičnih transporterera sa trakom zahteva dugačke transportne puteve usled ograničenog dozvoljenog nagiba trase. Zbog toga postoji potreba da se razmatra primena visokonagibnih transporterera koji bi savladali potrebnu visinsku razliku.

## 2 PRIMENA VISOKONAGIBNIH TRANSPORTERA SA TRAKOM U RUDNICIMA UGLJA

Osnovni problemi koji se javljaju u rudnicima uglja u Srbiji, kada je u pitanju transport, mogu se svrstati u nekoliko grupa, ali među najvažnije spadaju veliki broj transportnih jedinica, velike dužine transporta po toni dobijenog uglja, malo iskorišćenje transportnih sredstava, visoki troškovi održavanja opreme i transportnih prostorija i dr.

Velike dužine transportnih puteva nastaju kao posledica udaljenosti otkopa od istovarnih objekata na površini. Da bi se ove dužine skratile analizirane su mogućnosti primene tri vrste specijalnih transporterera: cevastih transporterera, transporterera sa uklopima i talasastim ivicama (Flexowell sistem) i transporterera sa pritisnom trakom (sendvič transporterera).

Razmatrajući mogućnosti primene cevastih transporterera i uzimajući u obzir sve prednosti i nedostatke, za rudnike uglja sa malom proizvodnjom, došlo se do zaključka da u sadašnjem trenutku nije ostvariva njihova primena iz sledećih razloga:

- it is not fully possible to secure the capacity of pipe formation and maintenance of a stable diameter due to underground room pressures and deformations;
- ununiform coal size consist with maximum lump dimensions requires large pipe diameters;
- unpossibility of manufacturing of belts for pipe formation in Serbian factories.

When considering the use of "Flexowell" type conveyors, the following facts represented the major shortcomings:

- "Flexowell" system requires an uniform small size consist;
- most components, including the carrying belt, cannot be produced in the country due to the current degree of Serbian factories development;
- the installation has a very high price that increases coal transport costs.

Pressure (sandwich) conveyors are applicable in near future in Serbian collieries due to below reasons:

- possibility of managing large inclines and heights up to 300 m with large output ranges;
- installation flexibility regarding transfer to other locations and relative tolerance to underground rooms regularity;
- construction simplicity enabling use of unified conveyor parts and assemblies, as well as use of classic belts;
- the amount of new special parts is relatively small and their manufacture is very simple;
- possibility of manufacturing nearly all parts in domestic transport means factories;
- lower prices compared with lifting height in relation with previously considered conveyors.

Figure 1 presents a diagram illustrating the relation of possible coal haulage distances to the surface. Curve 1 shows the relation between haulage length through the roadway and vertical shaft L and transport length by sandwich conveyor  $L_s$  for different angles  $\beta$ , while curve 2 shows the relation between classic belt conveyors lengths and  $L_s$  length.

- nije u potpunosti moguće ostvariti dobru sposobnost formiranja cevi i održavanje stabilnog prečnika s obzirom na pritiske i deformacije podzemnih prostorija,
- neujednačena granulacija uglja sa maksimalnim dimenzijama komada zahtevala bi jako velike prečnike cevi,
- nemogućnost proizvodnje traka za formiranje cevi u srpskim fabrikama.

Kod razmatranja primene vertikalnih transporterata tipa Flexowell za glavne nedostatke su konstatovane sledeće činjenice:

- sistem Flexowell zahteva ujednačenu granulaciju sa malim dimenzijama komada,
- većina delova, uključujući i noseću traku, u sadašnjem stepenu razvoja srpskih fabrika, se ne mogu proizvesti u zemlji,
- postrojenje ima visoku cenu koja poskupljuje transport uglja.

Transporteri sa pritisnom sendvič trakom se u bliskoj budućnosti mogu primeniti u rudnicima uglja Srbije iz sledećih razloga:

- mogućnost savladavanja velikih nagiba i visina do 300 m, sa širokim dijapazonima kapaciteta,
- fleksibilnost postrojenja u pogledu premeštanja na druge lokacije i relativna tolerantnost na regularnost podzemnih prostorija,
- jednostavnost konstrukcije koja omogućava primenu unificiranih delova i sklopova transporterata, kao i primenu klasičnih traka. Količina novih specijalnih delova je relativno mala, a njihova izrada je veoma jednostavna,
- mogućnost izrade skoro svih delova u domaćim fabrikama opreme za transport,
- niža cena prema visini dizanja u odnosu na prethodno razmatrane transporterere.

Na slici 1 je dat dijagram koji ilustruje odnos mogućih dužina transporta uglja na površinu. Kriva 1 predstavlja odnos dužina kroz hodnik i vertikalno okno L prema dužini transporta sendvič transporterom  $L_s$  za različite uglove  $\beta$ , a kriva 2 daje odnos dužina klasičnim transporterima sa trakom prema dužini  $L_s$ .

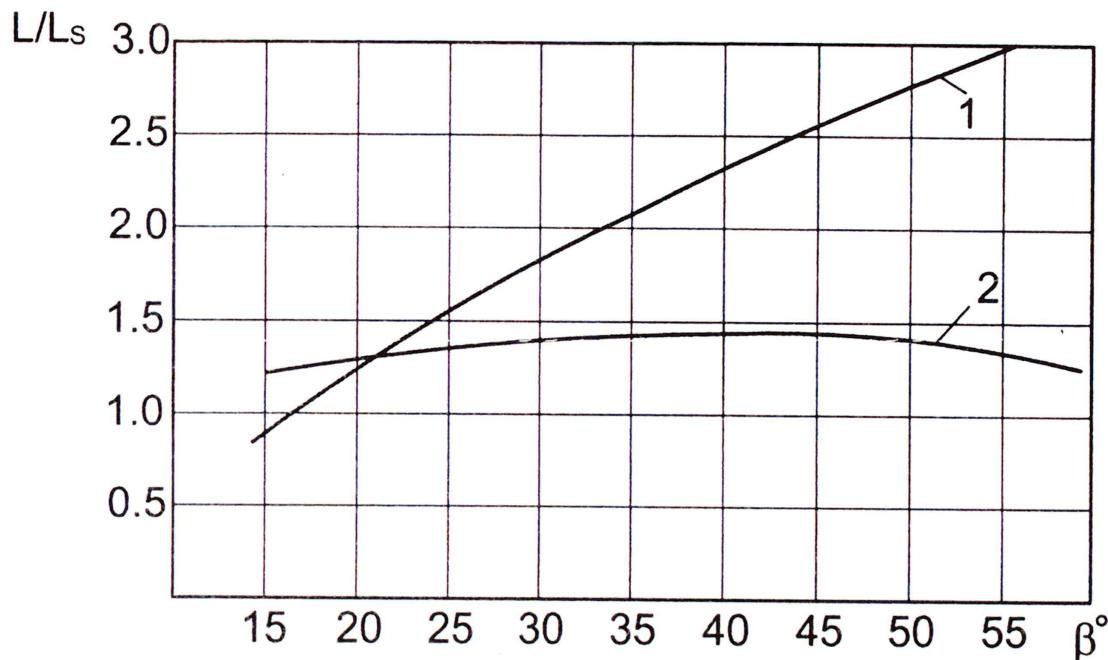


Figure 1 Relation between coal transport length through the roadway – shaft,  $16^{\circ}$  incline and sandwich conveyor inclined roadway

slika 1 Odnos dužina transporta uglja kroz hodnik-okno, niskop od  $16^{\circ}$  i kosu prostoriju za sendvič transporter

Past experience with application of pressure belt conveyors lead to a conclusion that it is very important to define correctly the pressure force acting onto the cover belt preventing material backslide. For collieries it was found justifiable to use sandwich conveyors whose both belts move by the same speed.

Belts wide 800 mm and 1000 mm with speeds between 1.3 and 2.0 m/s fully satisfy the need of production in Serbian underground collieries. Figure 2. shows the dependence of required pressure force on the cover belt on route incline angle. Curve 1 refers to a speed of 1.32 m/s, curve 2 to 1.7 m/s and 3 to a speed of 2.05 m/s. In the three cases belt width is 800 mm and medium size consist brown coal transport was analyzed.

Belts used for sandwich conveyors may have fabric plies or steel cords. Use of reinforced fibres is also possible, but due to high costs this is not appropriate for small collieries.

Iz dosadašnjih iskustava kod primene transporterera sa pritisnom trakom proisteklo je saznanje da je veoma važno definisati pritisnu silu koja deluje na pokrivnu traku i onemogućava klizanje materijala. Za rudnike uglja procenjeno je da je opravdano primeniti sendvič transporterere čije se obe trake kreću istom brzinom.

Za proizvodnju u srpskim rudnicima uglja sa podzemnom eksploatacijom mogu u potpunosti zadovoljiti transporteri sa trakom širine 800 i 1000 mm i brzinom od 1,3 do 2,0 m/s. Na slici 2 je prikazana zavisnost potrebne sile pritiska na pokrivnu traku od ugla nagiba trase. Kriva 1 se odnosi na brzinu od 1,32 m/s, kriva 2 na 1,7 m/s, a kriva 3 na brzinu od 2,05 m/s. Širina trake u sva tri slučaja je 800 mm, a analiziran je transport mrkog uglja srednje granulacije.

Trake koje se koriste za sendvič transporterere mogu biti sa tekstilnim ulošcima ili sa čeličnom kordom. Primena aramidnih vlakana je takođe moguća, ali, s ozirom na troškove, još nije realna za male rudnike uglja.

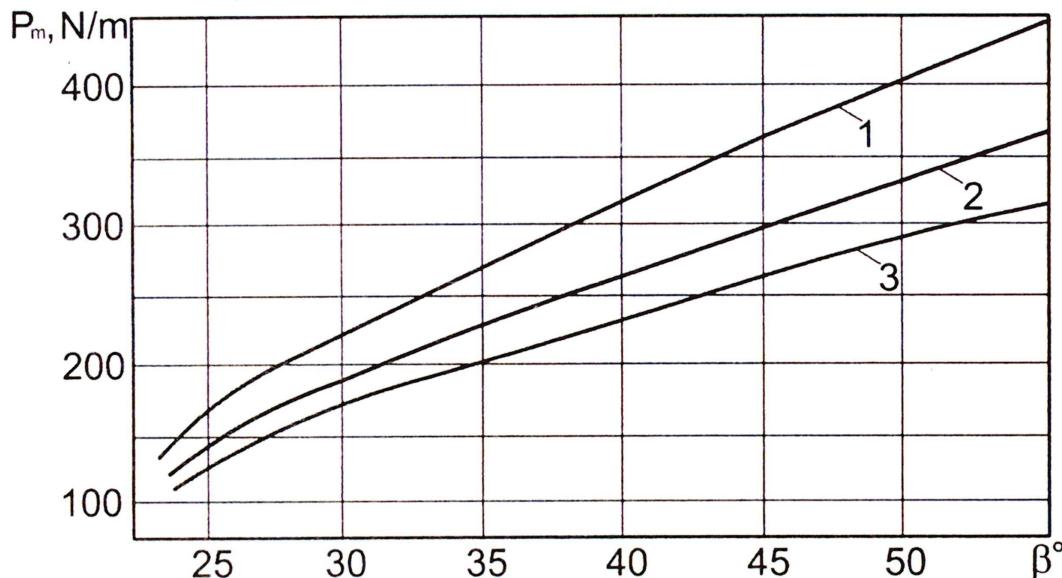


Figure 2 Dependence of pressures force on route angle of incline  
slika 2 Zavisnost pritisne sile od ugla nagiba trase

Experience gained with sandwich conveyors indicates that for heights upto 120 m belts with fabric plies may be successfully used, but for larger heights steel cord core belts are necessary. On the first Yugoslav Pressure belt conveyor in Copper Mine Majdanpek the cover belt was replaced after a relatively short operating period (2 years) because damages occurred. An analysis indicated that damage was caused by ununiform belt loading over an unit of time. The longitudinal profile of a belt loaded in this way is irregular (Fig. 3), requiring specific measures during loading in order to achieve an uniform material flow.

Iskustva koja postoje u primeni sendvič transportera govore da se do visine dizanja do 120 m mogu uspešno primeniti trake sa tekstilnim ulošcima, a za veće visine su neophodne trake sa jezgrom od čelične užadi. Na prvom transporteru sa pritisnom trakom u Srbiji u Rudniku bakra Majdanpek izvršena je izmena gornje trake posle relativno kratkog vremena eksploracije (2 godine), jer je došlo do oštećenja. Analizom je utvrđeno da je oštećenje nastalo usled neravnomernog nasipanja trake u jedinici vremena. Uzdužni profil ovako nasute trake je neregularan (slika 3), pa je bilo neophodno preduzet i određene mere prilikom utovara kako bi se postigao ravnomeran tok materijala.

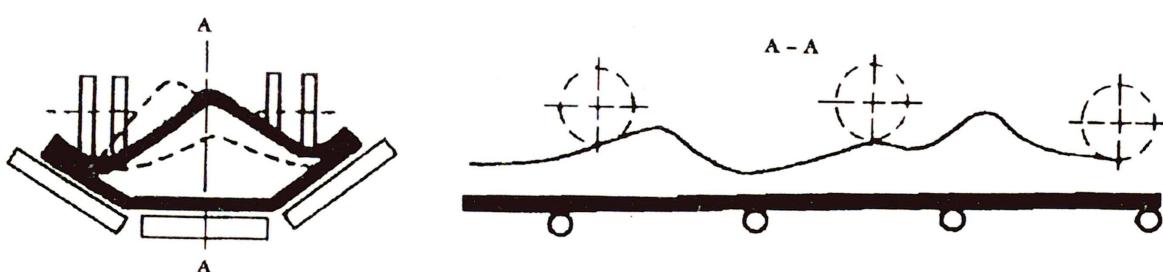


Fig. 3. Longitudinal profile during ununiform loading  
slika 3 Uzdužni profil kod neravnomernog nasipanja

In order to avoid this ununiformity, coal transport requires appropriate dosing of material onto the carrying belt. Research into the condition in Serbian collieries resulted in a formula for material cross-sectional area to be loaded onto the carrying belt in this case:

$$F = \frac{Bv(0,81B - 0,09)}{10v_d} \quad (1)$$

where: B - belt width, m;

v - both belts travel speed, m/s;

$v_d$  - velocity of material feeding onto the carrying belt, m/s.

The hourly output of conveyors with a pressure belt for inclines between  $30^\circ$  and  $45^\circ$  in collieries  $v_d = v$  will be:

$$Q_h = 360B\gamma_n(0,81B - 0,09) \text{ t/h} \quad (2)$$

Material loading onto high-angle conveyors represents a specific problem due to the great incline and possible particle bouncing and backward movement. Hence, material loading onto the carrying belt should be carried out under a much lower angle. Recommendations resulting from researches by author dealing with these problems indicate that the loaded belt may not be under an angle higher than  $10^\circ$  to  $15^\circ$ , and that the maximum angle at the point where the material enters into the sandwich may be  $18^\circ$ .

The vertical curve serving for belt transition from a lower to a steeper incline is limited by belt strains due to bending. Curve radius for concave bends is defined in dependence with allowed edges strain  $R_0$  and belt center buckling  $R_b$ :

$$R_0 \geq \frac{B^2 Z}{2X} \quad (3)$$

$$R_b \geq \frac{B^2 Z}{Y} \quad (4)$$

For vertical convex curves:

$$R_0 \geq \frac{B^2 Z}{X} \quad (5)$$

Za transport uglja, da bi se izbegla ova neravnomernost, neophodno je obezbediti pravilno doziranje materijala na noseću traku. Istraživanjem uslova u srpskim rudnicima uglja došlo se do izraza za površinu poprečnog preseka materijala koji treba u svakom trenutku da stupi na noseću traku:

$$F = \frac{Bv(0,81B - 0,09)}{10v_d} \quad (1)$$

gde su: B – širina trake, m,

v – brzina kretanja obe trake, m/s,

$v_d$  – brzina stupanja (dodavanja) materijala na noseću traku, m/s.

Časovni kapacitet transporter sa pritisnom trakom za nagibe od  $30$  do  $45^\circ$  u rudnicima uglja, pod uslovom da je  $v_d = v$ , bi bio:

$$Q_h = 360B\gamma_n(0,81B - 0,09) \text{ t/h} \quad (2)$$

Utovar materijala na visokonagibne transportere predstavlja određen problem usled velikog nagiba i mogućeg odskakanja čestica i povraćaja unazad. Zbog toga je neophodno da se utovar materijala na noseću traku vrši pod znatno blažim uglom. Preporuke nastale istraživanjem autora koji se bave ovom problematikom ukazuju na to da traka koja se utovara ne sme biti pod većim uglom od  $10$  do  $15^\circ$ , a da maksimalni ugao gde materijal ulazi u sendvič iznosi  $18^\circ$ .

Vertikalna krivina, koja služi za prelaz trake iz blažeg u strmiji nagib, je ograničena naprezanjima trake usled savijanja. Radijus krivine kod konkavnih krivina se određuje u zavisnosti od dozvoljenog naprezanja ivica  $R_0$  i izvijanja centra trake  $R_b$ :

$$R_0 \geq \frac{B^2 Z}{2X} \quad (3)$$

$$R_b \geq \frac{B^2 Z}{Y} \quad (4)$$

a za vertikalne konveksne krivine:

$$R_0 \geq \frac{B^2 Z}{X} \quad (5)$$

$$R_b \geq \frac{B^2 Z}{2Y} \quad (6)$$

where: X = 175(P<sub>r</sub>-P<sub>c</sub>)  
 Y = 175(P<sub>c</sub>-30B)  
 z = σ<sub>m</sub> n sinφ  
 B - belt width;  
 φ - belt trough lateral roller angle of incline;  
 n - number of belt plies;  
 σ<sub>m</sub> - belt module;  
 P<sub>r</sub> - nominal belt operating tension;  
 P<sub>c</sub> - axial belt tension.

For low output collieries trough with lateral roller inclines φ between 20° and 30° are appropriate. From the aspect of size consist higher angles are more suitable since this allows better cover belt overlapping.

Pressure belt conveyors (according to [1]) should meet a few important conditions to be applicable in mines:

- every sandwich should be installed so that it enables fast and easy repair, and easy belt cleaning should also be possible;
- during loading the material must be consolidated and in a standstill state prior to entering into the sandwich;
- pressure force on the cover belt should be applied by an elastic system with maximum elimination of load concentration;
- the cover belt may not hinder the flow of lumps larger than designed or inadequately oriented, i. e. the pressure belt must be mounted flexibly.

All above conditions are achievable in collieries, allowing the use of sandwich conveyors in small Output mines too. Preliminary investigations in three Serbian collieries indicated that application of this transportation method will decrease the costs of coal transport to the surface by 25 to 30%.

## CONCLUSION

Application of sandwich conveyors in collieries for mined material hoisting to the surface is possible and economically justified, this type of

$$R_b \geq \frac{B^2 Z}{2Y} \quad (6)$$

gde su: X = 175(P<sub>r</sub>-P<sub>c</sub>),  
 Y = 175 (P<sub>c</sub>-30 B),  
 Z = σ<sub>m</sub> n sinφ,  
 B - širina trake,  
 φ - ugao nagiba bočnih valjaka korita trake,  
 n - broj uložaka trake,  
 σ<sub>m</sub> - čvrstoća na kidanje uložaka trake,  
 P<sub>r</sub> - nominalna radna zategnutost trake,  
 P<sub>c</sub> - osovinsko zatezanje trake.

Za rudnike uglja sa manjom proizvodnjom u potpunosti odgovaraju korita sa nagibom bočnih valjaka od 20 i 30°. Sa aspekta granulacije pogodniji su veći uglovi, jer u tom slučaju je moguće bolje naleganje pokrivne trake.

Transporteri sa pritisnom trakom (prema [1]), treba da ispune nekoliko važnih uslova da bi bili primenjeni u rudnicima uglja i to:

- svaki sendvič transporter mora biti postavljen tako da omogućuje brzu i laku popravku postrojenja, a istovremeno mora biti omogućeno lako čišćenje traka,
- prilikom utovara materijal mora biti konsolidovan i u stanju mirovanja pre nego što uđe u sendvič,
- pritisna sila na pokrivnu traku mora biti nanošena preko elastičnog sistema sa što većom eliminacijom koncentracije opterećenja,
- pokrivna traka ne sme ometati protok komada većih od predviđenih ili nepravilno usmerenih, odnosno pritisna traka mora biti fleksibilno postavljena.

Svi navedeni uslovi se mogu postići u rudnicima uglja, što omogućava primenu sendvič transportera i u malim proizvodnim pogonima. Preliminarna istraživanja u tri rudnika uglja u Srbiji ukazuju da bi se primenom ovog načina transporta smanjili troškovi transporta uglja na površinu za 25 do 30%.

## ZAKLJUČAK

Primenom sendvič transportera u rudnicima uglja za izvoz iskopine na površinu je sasvim moguća i ekonomski opravdana. Ova vrsta transportnih

transportation means is characterized by simple construction, high output, capability of managing fairly large height differences (even up to 300 m), while incline limitations practically do not exist. In addition, pressure belt conveyors are highly flexible, allowing their ready shifting and movement to other imposed by applications of this type of transportation means. Of particular importance is the fact that application of pressure belt conveyors decreases capital investment into construction of underground room in line with decrease of maintenance and manpower costs.

sredstava se odlikuje jednostavnom konstrukcijom, ima veliki kapacitet, može da savlada dosta velike visinske razlike (i do 300 m), ograničenja u pogledu nagiba praktično ne postoje. Pored toga transporteri sa pritisnom trakom su veoma fleksibilni, što omogućava njihovo lako premeštanje i pomeranje na drugu lokaciju uz prilagođavanje dužine i ugla nagiba. Posebno je značajno da se primenom transportera sa pritisnom trakom smanjuju ulaganja u podzemne prostorije, a smanjeni su troškovi održavanja i radne snage.

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