



THE LATEST DEVELOPMENT TENDENCIES IN COMBINED CONVEYANCE AT OPENCAST METAL MINES

NOVE TENDENCIJE U RAZVOJU KOMBINOVANIH TRANSPORTNIH SISTEMA NA POVRŠINSKIM KOPOVIMA METALIČNIH MINERALNIH SIROVINA

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Abstract: In parallel with a gradual deterioration of metal ore quality and with greater mining depths the amounts of ore and overburden that must be extracted or removed become larger with a view to providing cost-effective production. Large-scale mining and great depths require longer conveying routes and capacities, which significantly increases the cost price of metal ore mining. Recognizing the previously stated reasons it may be noted that the latest development of haulage equipment for opencast metal mines tend to shorten the haulage routes with the view to reducing the transportation costs, which participate substantially in the overall cost of ore production.

Key words: Open-pit mine, kombine transport, truck, slope hoisting system

Apstrakt: Sve većim osiromašenjem rude metala, kao i povećanjem dubine kopova, povećavaju se količine mineralne sirovine i jalovine koje se moraju otkopati, a iz razloga ekonomičnosti proizvodnje. Povećanjem dubine i masovnijom proizvodnjom mineralnih sirovina, povećavaju se transportne dužine i zahtevi za većim kapacitetima transporta, što znatno utiče na cenu koštanja eksploatacije metalnih mineralnih sirovina.

Iz gore navedenih razloga trendovi razvoja nove opreme za transport na površinskim kopovima metalnih mineralnih sirovina, upravo idu u tom pravcu - smanjenje dužina transportnih puteva, a u cilju smanjenja cene koštanja transporta, koja čini značajnu stavku u ukupnoj ceni proizvodnje rude..

ključne reči: površinski kop, kombinovani transport, kamion, izvozni lift

1 INTRODUCTION

The most convenient and the most frequently applied mining method at opencast metal mines is the discontinuous mining method, which usually implies discontinuous conveyance. The basic component parts of a discontinuous conveyance are the means of transportation that operate in a non-continuous mode: hydraulic excavators, trucks, loaders, track-mounted vehicles, stationary, semi-stationary and mobile crushers etc.

1 UVOD

Na površinskim kopovima metalnih mineralnih sirovina najviše je primenjena diskontinualna tehnologija otkopavanja. Diskontinualni transportni sistemi se primenjuju obično u rudnicima sa diskontinualnim načinom otkopavanja. Elementi diskontinualnih transportnih sistema, u zavisnosti od primenjenog načina transporta, su transportna sredstva koja imaju diskontinualan način rada: hidraulični bageri, kamioni, utovarači, sredstva šinskog transporta, stacionarna, polustacionarna i mobilna drobilna postrojenja i dr.

Discontinuous conveyance has significant advantages over other means of transportation such as simple and easy conveyance of lump-size blasted materials and very good mobility and adaptability to working site conditions. On the other hand, these systems also have several important shortcomings such as; increased consumption of liquid fuels that gives rise to air pollution and longer transport roads that require constant maintenance, which considerably increase the costs of production. In order to overcome successfully these disadvantages the implementation of combined conveyance systems is becoming growingly accepted.

2 CONVEYANCE SYSTEMS AT OPENCAST MINES

The use of trucks for ore and waste transportation at opencast mines provides a larger flexibility of mine conveyance systems. However, the advantages of truck transportation are valid only under certain specific circumstances such as the possibility of easy and inexpensive construction of haulage roads at each working bench and with the slope determined for the corresponding type of transportation.

The ore or the waste material, either previously blasted or not, is loaded into trucks by means of loading machines and shovel excavators. Then, the material is transported by haulage routes, which usually run along the edge of the opencast mine, and then conveyed out of the mine limits towards the crushing and processing plants. This type of ore or waste transportation at opencast mines comes up against a large number of difficulties and problems that require careful consideration. Such as, the stability of bench slopes and maintenance of haulage roads, substantial fuel consumption due to longer conveying distances, truck maintenance etc.

In order to overcome the difficulties stated above several alternative solutions for combined conveyance were offered. Combined conveyance systems imply that trucks may transport ore or waste inside the mine limits, while for further conveyance it is possible to apply other means of transportation.

Up to now, good results have been obtained with the combined transportation based on truck – belt conveyor system. It is possible to combine different conveyance systems inside the mine limits, outside the mine and at waste disposal sites as presented in Figure 1.

However, in spite of the good performance features that were obtained with these combined conveyance systems the latest tendencies in metal ore haulage at deep opencast mines are oriented towards the development of inclined elevators and skip plants.

Diskontinualni transportni sistemi imaju značajne prednosti u odnosu na ostale vidove transporta, zbog jednostavnog i lakog transporta izminiranog krupnokomadastog materijala i veoma velike mobilnosti i mogućnosti prilagođavanja mestu eksploatacije. Međutim, velika potrošnja tečnih goriva, samim tim povećanje zagađenja radne sredine izduvnim gasovima, kao i značajno povećanje troškova proizvodnje povećanjem dužine transportnih puteva, održavanje transportnih trasa, utiču na sve veću primenu kombinovanih transportnih sistema.

2 TRANSPORTNI SISTEMI NA POVRŠINSKIM KOPOVIMA

Korišćenje kamiona za prevoz rude i jalovine na površinskim kopovima omogućilo je veću fleksibilnost rudničkog transporta. Ipak prednosti kamionskog transporta se podrazumevaju samo u određenim uslovima primene kao što su mogućnost lake i jeftine gradnje transportnih puteva po radnim etažama sa nagibima koji su prilagođeni tom tipu transporta.

Ruda ili jalovina se utovara u kamione, sa ili bez prethodnog miniranja, pomoću utovarivača ili bagera kašikara. Zatim se transportnim putevima ruda konturama površinskog kopa odvozi van kopa, do mesta drobljenja ili prerade. Ovakav način transporta rude i jalovine na površinskim kopovima nailazi na veliki broj problema koje treba rešavati: stabilnost etažnih kosina, stabilnost i održavanje transportnih puteva, velika potrošnja goriva za velike dužine transporta, održavanje kamiona i sl.

Iz svih navedenih razloga i problema nastala su alternativna rešenja sa kombinovanom tehnologijom transporta mineralnih sirovina. Kombinovanim sistemima transporta ruda i jalovina se transportuju unutar konture površinskog kopa, a za odvoz rude ili jalovine sa kopa koristi se neki drugi sistem transporta.

Do sada se kao dobar pokazao kombinovani sistem transporta kamioni - trakasti transporter. Moguće kombinacije različitih sistema transporta unutar kopa, van kopa i na odlagalištima prikazane su na slici 1.

Međutim, i pored svih dobrih osobina ovih kombinovanih transportnih sistema, nove tendencije u razvoju sistema za transport metalčnih mineralnih sirovina na dubokim površinskim kopovima, idu u pravcu razvoja opreme za izvoz rude i jalovine pomoću kosih izvoznih liftova i skipova.

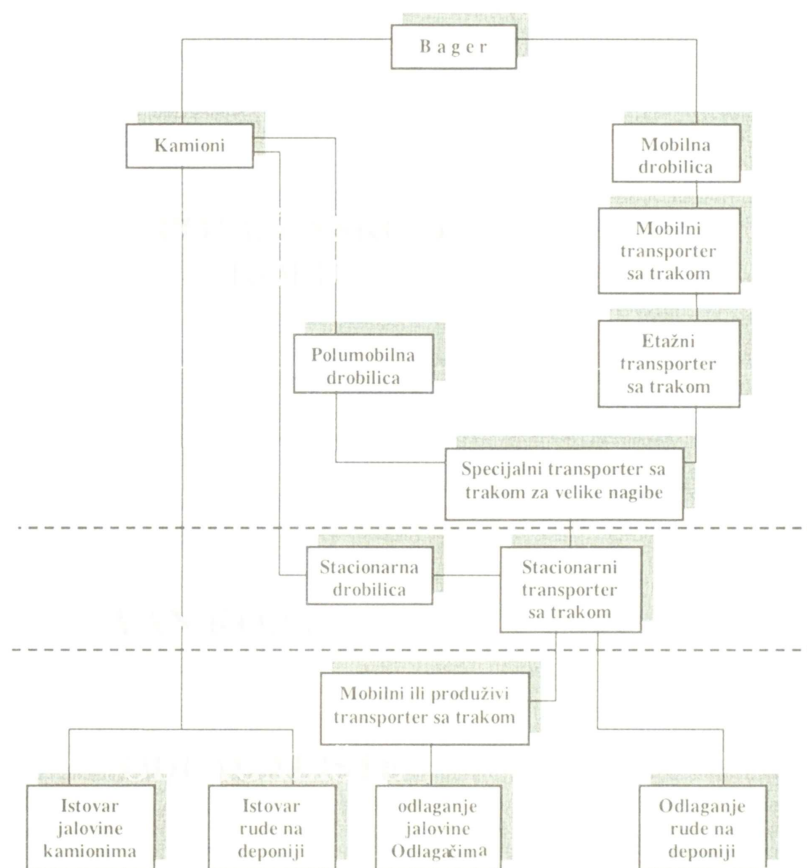


Figure 1 Possibility combination of transportation
slika 1 Dijagram mogućih kombinacija transporta

3 INCLINED ELEVATORS

The company SIEMAG-GHH Mining Technology has achieved undoubtedly the greatest success in the latest development of inclined elevators for opencast mines. This company designs elevators for hoisting of heavy-load trucks intended for deep opencast mines. Figure 2 shows the operation flow chart of the elevator for heavy-load trucks.

The optimise transportwhile maintaining flexibility offered by truck transport, Siemag Transplan GmbH has developed a slope hoistinmg plant. The advantage lines of the transport time being curtailed by the diference in height being rapidly overcome. While the trucks move upwards at less than 3 m/s on a slope of 10% at the maximum, a slope hoisting plant can overcome the mines natural angle of repose of over even 50° at 8 m/s. This means that fewer trucks are on the slope at one time and the number of vehicles needed is therefore correspondilngly reduced. Whereas only one vehicle is on the slope with the slope hoisting plant at one time, conventional transport with trucks requires up to 12 vehicles, depending on the depth involved, on the ramp alone for the same volume to be conveyed (for depth 350 m).

3 KOSI IZVOZNI LIFTOVI

Najveći uspeh u dosadašnjem razvoju kosih izvoznih liftova za površinske kopove, nesumljivo je postigla firma SIEMAG-GHH Mining Technology iz Nemačke. Oni su projektovali izvozne liftove za izvoz kamiona velike nosivosti za duboke površinske kopove. Na slici 2 je prikazana šema rada izvoznog lifta za kamione velike nosivosti.

Da bi se ubrzao i pojeftiniji transport uz zadržavanje fleksibilnosti, razvijeni su tzv. kamionski liftovi. Prednost ovog sistema se ogleda u velikom smanjenju trajanja ciklusa kamiona usled skraćanja transportnih puteva. Kamioni se na nagibu od 10% kreću brzinama manjim od 3 m/s, dok se primenom liftova može postići brzina od 8 m/s po nagibu završne kosine kopa (50° i više). Ovo znači da se kamion podiže na površinu za samo dva minuta (uključujući i vreme potrebno da se kamion postavi na lift i da side sa njega, dok bi za savladavanje visinske razlike kretanjem po putevima, bilo potrebno i preko 20 minuta. I dok je pri primeni lifta na kosini samo jedan kamion u jednom trenutku, primenom klasičnih transportnih šema potrebno je i do 12 kamiona kako bi se postigao isti kapacitet (za kop dubine oko 350 m).

The slope hoisting plant is designed for transport on the natural angle of response of the open pit mine and can be lengthened for increasing depth. It is set up as a single conveyance plant with counterweight, avoiding time-relevant synchronisation of operation at the loading points.

It is designed for two loading points, one down in the mine and a second one above on the edge at a height appropriate for the purpose. Trucks are transported on a platform. Down in the mine, the fully laden trucks drive to the loading point, at which one vehicle drives onto the transport platform in each instance. The slope hoisting plant conveys the truck out of the mine to the upper loading point where it leaves the plant. The driver accompanies his vehicle during hoisting so that no change of driver is necessary. At the upper loading point, an empty truck drives onto the platform for the downward trip immediately after the platform is free. In this way, the plant runs constantly loaded, each time a vehicle changes at the loading points.

Lift je projektovan za transport pod uglom prirodnog nagiba kopa i može se po potrebi produžavati sa porastom dubine kopa. Konstrukcijski predstavlja samostalni izvozni sistem sa kontrategom, čime se izbegava vremenski zahtevno koordiniranje operacija na mestima utovara kamiona na lift.

Postoje dva utovarna mesta, jedno na "dnu", a drugo na "vrhu". Kamioni se tokom izvoza nalaze na platformi. Na donjoj etaži, puni kamioni čekaju na ulaznom mestu i po jedan u svakom ciklusu ulaze na platformu. Lift izvozi kamion duž kosine površinskog kopa na najvišu tačku kopa. Vozač je sve vreme u vozilu, pa zamena vozača nije neophodna u toku vožnje i izvoza kamiona. Na gornjoj ulaznoj tački, kada pun kamion napusti izvozni lift, prazan kamion ulazi na platformu čim se ova oslobodi i zatim se spušta. Na ovaj način, postrojenje je konstantno u radu, i ima pun kapacitet rada.

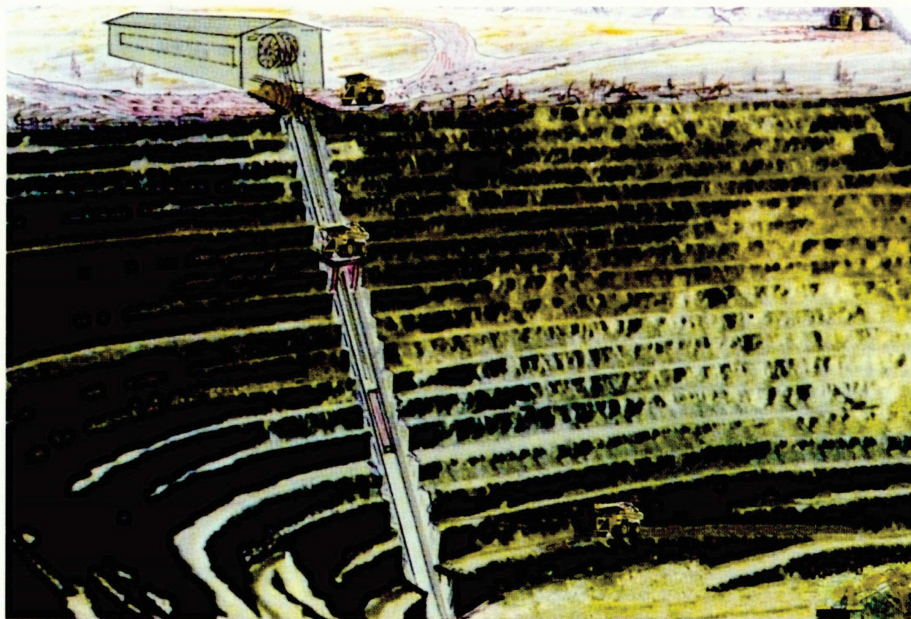


Figure 2 Slope hoisting system for truck
slika 2 Izvozni sistem za kamione velike nosivosti

The travel path is a concrete or steel construction, and which the rails for the transport platform and counterweight are attached. It has appropriate foundations in the rock. It is designed trough-shaped, as the counterweight runs under the transport platform. Rope rollers take over the carrier function for the ropes on the slope section. The transport platform and the counterweight are attached to 6 to 8 ropes and are powered by means of a multirope friction winder. The winder is appointed in a machine house above the top

Putanja lifta je betonska ili čelična konstrukcija po kojoj se nalaze šine za transportnu platformu i kontrateg. Cela konstrukcija je ankerisana u podlogu. Kontrateg pri kretanju prolazi ispod platforme. Užad prelazi preko koturača koje su smeštene na gornjoj sekciji. Transportna platforma i kontrateg su pričvršćeni na 6 do 8 užadi. Pogon se je smešten u objektu iznad gornje utovarne tačke. Motor je smešten u pogonskom bubnju, pošto je ovaj dovoljno velik.

loading point. The motor is appointed in the driving pulley, since the winder is big enough with regard to diameter and width. The plant is designed for operation without tail ropes as weight compensation for the hoisting ropes. In this manner, here is no equipment necessary at the bottom end of the hoisting plant, as such equipment would be expensive to re-install for a greater depth.

The loading points comprise the ramps and pertinent concrete construction in the area between the ramp and hoisting plant. Platform arrestors are provided at the loading points, which are run out when the transport platform arrives, ensuring that the transport platform is held in positions when the load changes by the trucks arriving and departing. At the same time, this reduces the dynamic load on the ropes. When the bottom loading point is transferred, as a result of deeper mining progression, first of all the new ramps and the civil construction, for the loading station are completed. All that has to be done now to move the loading point properly is to transfer to mechanical equipment, and to let out the ropes out of the magazines. This work can be done in a few shifts.

The slope hoisting plant is equipped with energy-dissipating retardation system to protect personnel and the plant in case of overwinding which would only occur if several independent safety features failed.

The basic advantages of this system are as follows:

- Low power consumption,
- Low fuel/oil consumption,
- Reduced manpower
- Significantly reduced costs for haulage road construction and maintenance,
- Reduced environmental pollution.

The basic disadvantages of this system are the following:

- Considerable initial investments,
- Purchasing and maintenance of hoisting ropes.

The designers of this solution worked out a study proving its economic viability. Namely, this conveyance system has proved to be cost-effective and regardless of considerable initial investments it starts to pay off as the exploitation life of the system and the depth of the mine increase, so that the savings eventually overcome the substantial initial investments made. The diagram given in Figure 3 demonstrates this statement.

Sistem je tako konstruisan da ne postoji povratna užad, čime se eliminiše potreba za bilo kakvim dodatnim delovima konstrukcije na donjem delu izvoznog postrojenja. Ovim se postiže jednostavnije produženje, odnosno povećanje visine podizanja kamiona liftom, u slučaju povećanja dubine površinskog kopa i smanjuje se cena i složenost konstrukcije čitavog postrojenja.

Na mestima utovara su postavljene betonske rampe uz koje se kamioni penju na platforme. Pri utovaru platforme stoje na nosačima, tako da ne dolazi do njihovog pomeranja, a osim toga i dinamička opterećenja kojima su izložena užad su daleko manja, u momentima nailaska i silaska kamiona sa platforme. Pri premeštanju donje utovarne/istovarne tačke, kao posledice produblivanja kopa, prvo se izrade rampe i građevinska konstrukcija na novoj lokaciji. Preostaje samo da se premesti mehanička oprema i da se produže užad. Za sav ovaj posao dovoljno je nekoliko smena.

Lift je opremljen sigurnosnim sistemom, koji služi za zaštitu radnika koji opslužuju i koriste postrojenje, kao i za zaštitu izvoznog lifta. U slučaju da dođe do kidanja užadi, (a što se može desiti samo ukoliko se prekrši više sigurnosnih propisa), katastrofa bi bila izbegnuta.

Osnovne prednosti su:

- manja potrošnja energije,
- smanjenje potreba za naftom,
- manji broj potrebnog radnog osoblja,
- značajno manja cena troškova izgradnje i održavanja transportne trase,
- smanjenje zagađenja životne sredine.

Nedostaci ovih sistema su:

- velika startna investiciona ulaganja,
- potreba za nabavkom i održavanjem izvoznih užadi,

Bez obzira na to što se kao nedostatak smatra veliko inicijalno ulaganje u ovaj način transporta, studijom koju su uradili projektanti ovog rešenja, dokazano je da se ovakav način transporta na površinskim kopovima, sa povećanjem godina eksploatacije, kao i dubine kopa, uštede koje se postižu nadmašuju početnu veliku cenu ulaganja u ovaj sistem. To je predstavljeno na dijagramu na slici 3.

The second drawback may be overcome by implementing state of the art technologies for rope manufacturing for special-purpose performance in conditions of opencast metal mining.

Drugi nedostatak je moguće rešavati primenom novih tehnologija proizvodnje užadi za posebne režime rada na površinskim kopovima metalčnih mineralnih sirovina.

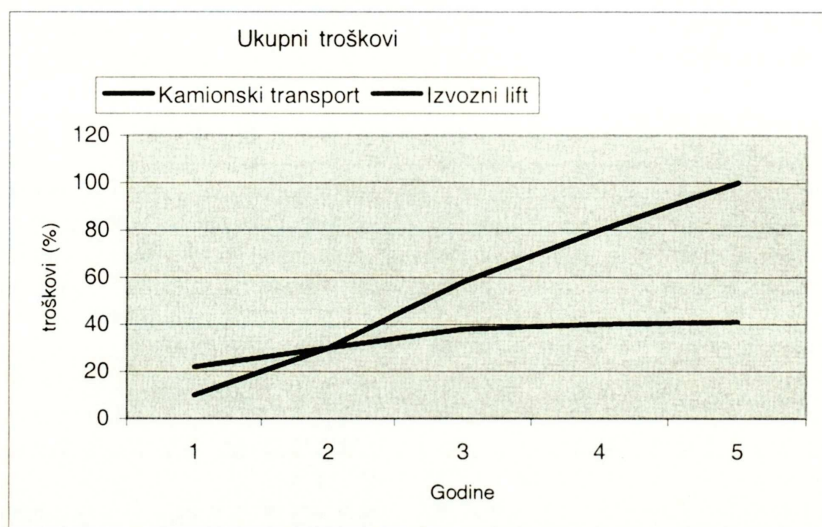


Figure 3 Diagram of total cost (investment and operating cost)
slika 3 Dijagram ukupnih troškova (investicionih i eksploatacionih)

3.1 Latest Tendencies in Rope Manufacturing

The ropes installed the machinery that operates at opencast mines are constantly subjected to stress and strain, which cause elastic or permanent deformations and damages. Moreover, apart from this the ropes are constantly exposed to adverse impacts of abrasive materials that are excavated weathering, climatic conditions, temperature changes etc.

In conditions of opencast mining the ropes are constantly exposed to a series of adverse impacts, from mechanical loading to decay due to abrasive and wet working environment (the presence of water, rain and snow, inadequate storage of spare ropes etc.). Considering this the rope manufacturing industry is trying to cope with such requirements and improve rope design features in order to mitigate decaying due to weathering and other aggressive impacts that appear in such working environments. At the same time the basic physical, mechanical and other rope design features should be preserved.

Special-purpose heavy-duty ropes designed and manufactured for rough conditions by the German company CASAR Drahtseilwerk Saar are listed further on.

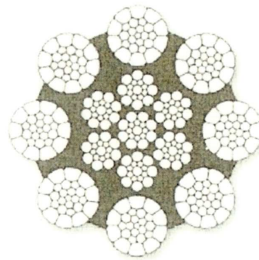
3.1 Nove tendencije u razvoju užadi

Užad koja se koriste kod mehanizacije na površinskim kopovima, izložena su stalnim opterećenjima usled rada mehanizacije, što kao rezultat ima elastične ili trajne defomacije i oštećenja. Međutim, pored ovih uzroka oštećenja užadi, ona trpe i konstantne štetne uticaje abrazivnih materijala koji se otkopavaju, kao i uticaje atmosferskih padavina, promena temperatura i sl.

Kako su užad na površinskim kopovima pored mehaničkih opterećenja, izložena i propadanju usled rada u abrazivnoj i mokroj sredini (voda na površinskim kopovima, kiša i sneg, neadekvatne prostorije za smeštaj rezervnih užadi i dr.), to se u novije vreme teži proizvodnji užadi, koja svojim konstrukcionim karakteristikama postižu značajnije rezultate u smanjenju propadanja užadi usled dejstva atmosferskih padavina i ostalih razarajućih elemenata koji su prisutni u radnoj sredini. Pri tom se mora voditi računa da se osnovne fizičko-mehaničke i druge osobine užadi ne dovode u pitanje.

U daljem tekstu dat je pregled užadi specijalno konstruisanih i proizvedenih za rad u teškim i abrazivnim uslovima radne sredine, nemačke firme CASAR Drahtseilwerk Saar.

TURBOPLAST

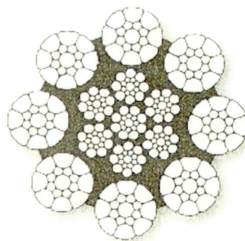


Attributes: Is an 8-strand rope made out of compacted outer strands, is fully lubricated, has a plastic layer between the steel core and the outer strands, has a very high breaking load and a good resistance against drum crushing.

Atributi: Uže od 8 strukova u spoljašnjem sloju, potpuno podmazano. Između čeličnog jezgra i spoljašnjih strukova se nalazi sloj plastike. Veoma visoke prekidne čvrstoće i dobre otpornosti na gnječenje na bubnju.

Normal diameter	Metalic area	Weight	Calculated aggregate breaking load with tensile strenght of wire				Minimum breaking load with tensile strenght of wire			
			1770 N/mm ²		1960 N/mm ²		1770 N/mm ²		1960 N/mm ²	
			kN	t	kN	t	kN	t	kN	t
30	470.7	409.6	833.2	84.97	922.7	94.09	712.8	72.49	789.3	86.06
40	837.9	729.0	1483.1	151.23	1642.3	167.47	1260.3	128.16	1395.5	142.40
50	1301.3	1132.1	2303.2	234.86	2550.5	260.07	1985.0	201.87	2198.1	224.30
60	1873.8	1630.2	3316.6	338.20	3672.6	374.51	2860.7	290.92	3167.8	323.25
70	2465.6	2145.1	4364.2	445.02	4832.6	492.79	3797.3	386.17	4205.0	429.08

DUROPLAST

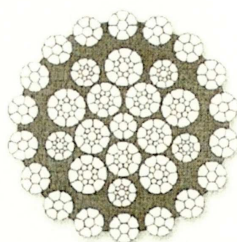


Attributes: is an 8-strand rope made out of compacted outer strands, is fully lubricated, has a plastic layer between the steel core and the outer strands, giving the rope a high structural stability, avoiding internal rope destruction and protecting the core against corrosive environment, has a very high breaking load and a good abrasion resistance and is very resistant against abrasion.

Atributi: Uže od 8 strukova u spoljašnjem sloju, potpuno podmazano. Između čeličnog jezgra i spoljašnjih strukova se nalazi sloj plastike koji daje visoku strukturnu stabilnost, čime se izbegava unutrašnje razaranje užeta i delovanje korozivne sredine. Visoke prekidne čvrstoće i otpornosti na abraziju.

Normal diameter	Metalic area	Weight	Calculated aggregate breaking load with tensile strenght of wire				Minimum breaking load with tensile strenght of wire			
			1770 N/mm ²		1960 N/mm ²		1770 N/mm ²		1960 N/mm ²	
			kN	t	kN	t	kN	t	kN	t
10	51.1	44.4	90.4	9.22	100.1	10.21	77.7	7.93	86.1	8.78
20	203.8	177.3	360.8	36.79	399.5	40.74	310.3	31.64	343.6	350.04
30	458.6	399.0	811.8	82.78	898.9	91.67	698.1	71.19	773.1	78.83
40	815.4	709.4	1443.2	147.17	1598.1	162.96	1241.2	126.56	1374.4	140.15
50	1270.2	1105.1	2248.3	229.26	2489.7	253.87	1933.5	197.17	2141.1	218.33

POWERPLAST



Attributes: is a rotation resistant hoist rope made out of compacted strands, is fully lubricated, has a plastic layer between the steel core and the outer strands, has a high breaking load and good resistance against drum crushing.

Atributi: Izvorno uže otporno na uvrtnje, potpuno podmazano. Između čeličnog jezgra i spoljašnjih strukova se nalazi sloj plastike. Veoma visoke prekidne čvrstoće i dobre otpornosti na gnječenje na bubnju.

Normal diameter	Metalic area	Weight	Calculated aggregate breaking load with tensile strenght of wire				Minimum breaking load with tensile strenght of wire			
			1770 N/mm ²		1960 N/mm ²		1770 N/mm ²		1960 N/mm ²	
			kN	t	kN	t	kN	t	kN	t
mm	mm ²	kg/%m								
12	82.2	74.8	145.4	14.83	161.0	16.42	118.2	12.10	103.8	13.30
20	229.5	208.9	406.3	41.43	449.9	45.88	329.3	33.49	362.2	36.90
30	515.9	469.5	913.2	93.12	1011.2	103.11	738.1	75.30	817.4	83.40
40	919.5	836.7	1627.4	165.95	1802.1	173.77	1360.0	138.00	1462.0	149.10
50	1433.6	1304.6	2537.5	258.75	2809.9	286.53	2069.0	211.10	2292.0	233.70

4 PRACTICAL EXPERIENCE GAINED IN YUGOSLAV MINES

In Yugoslavia, in deep opencast copper mines the material is conveyed by means of discontinuous (truck) or combined (truck-crusher-belt conveyor) systems. Considering the high price of the vehicles, high working expenses and maintenance charges it is obvious that the transportation costs take the major share in overall production costs, amounting to about 50%. In our mines the effective use of vehicles reaches about 55% during the first year. This percentage drops for about 5% each year in the course of the first 8 years of exploitation.

The possibilities of such conveyance-hoisting systems were roughly estimated using the experience gained in our mines. The estimates were based on haulage road lengths and required transportation times.

Transportation times:

$$T = t_u + t_m + t_i + t_v, \quad (1)$$

Where : t_u - loading time 9 min,

t_m - time for manevar 1.5 min,

t_i - unloading time 1.5 min,

t_v - driving time,

4 NEKA ISKUSTVA JUGOSLOVENSKIH KOPOVA

U dubokim jugoslovenskim površinskim kopovima bakra transport materijala se obavlja diskontinualnom (kamionski) ili kombinovanom (kamion - drobilica - trakasti transporter) tehnologijom transporta. Zbog visoke cene vozila i visokih troškova eksploatacije i održavanja, transport ima najveće učešće u troškovima proizvodnje, koje iznosi i do 50%. Efektivno iskorišćenje vozila, na našim kopovima u prvoj godini eksploatacije iznosi oko 55%. Sa starenjem vozila iskorišćenje opada oko 5% godišnje u periodu korišćenja od 8 godina.

Na primeru naših kopova izvršice se gruba procena mogućnosti primene ovakvih transportno-izvoznih sistema u funkciji dužine transportnih puteva i potrebnog vremena vožnje iskopine.

Vreme vožnje kamionima iznosi:

$$T = t_u + t_m + t_i + t_v, \quad (1)$$

gde je: t_u - vreme utovara 9 min,

t_m - vreme manevrisanja 1.5 min,

t_i - vreme istovara 1.5 min,

t_v - vreme vožnje,

$$T = 12 + t_v, \quad (2) \qquad T = 12 + t_v, \quad (2)$$

$$t_v = \frac{L}{v_p} + \frac{L}{v_{pr}} = \frac{L}{13} + \frac{L}{18} = \frac{31 \cdot L}{234}, \quad (3) \qquad t_v = \frac{L}{v_p} + \frac{L}{v_{pr}} = \frac{L}{13} + \frac{L}{18} = \frac{31 \cdot L}{234}, \quad (3)$$

Where: v_p - full truck speed
13 km/h,
 v_{pr} - empty truck speed
18 km/h,

gde je: v_p - brzina vožnje punim kamionom
13 km/h,
 v_{pr} - brzina vožnje praznim kamionom
18 km/h,

Haulage time in system with slope hoisting plant:

Vreme vožnje kamionima u kombinaciji sa izvoznim liftom iznosi:

$$T = t_u + t_m + t_i + t_v, \quad (4)$$

$$T = t_u + t_m + t_i + t_v, \quad (4)$$

$$t_v = \frac{L}{v_p} + \frac{L}{v_{pr}} = \frac{L}{13} + \frac{L}{18} = \frac{31 \cdot L}{234} + l_{vi}, \quad (5)$$

$$t_v = \frac{L}{v_p} + \frac{L}{v_{pr}} = \frac{L}{13} + \frac{L}{18} = \frac{31 \cdot L}{234} + l_{vi}, \quad (5)$$

gde je: l_{vi} - haulage time with slope hoisting plant.

gde je: l_{vi} - vreme vožnje liftom.

The lengths of haulage roads used for analysis are presented in the Figure 4. The analysis considers the following mine depths: 50, 100, 200, 300, 400 and 500 m are presented in Table 1. Figure 5 displays the results obtained on the basis of previous calculations.

Šema transporta data je na slici 4. Analiza je izvršena za dubine kopa od 50, 100, 200, 300, 400 i 500 m i data je u tabeli 1. Dobijeni rezultati analize prikazane su na dijagramu na slici 5.

Table 1
Tabela 1

Deep of mine (m)	Slope angle (°)	Truck transport (m)	Hoisting time (min)	Truck Lift System (m)	Hoisting time (min)
50	72	1200	9.5	800	6.3
100	47	1800	14.5	900	7.1
200	36	2300	18.2	1000	7.9
300	32	2800	22.2	1200	9.5
400	30	3400	27.0	1500	11.9
500	28	4500	35.0	1800	18.2

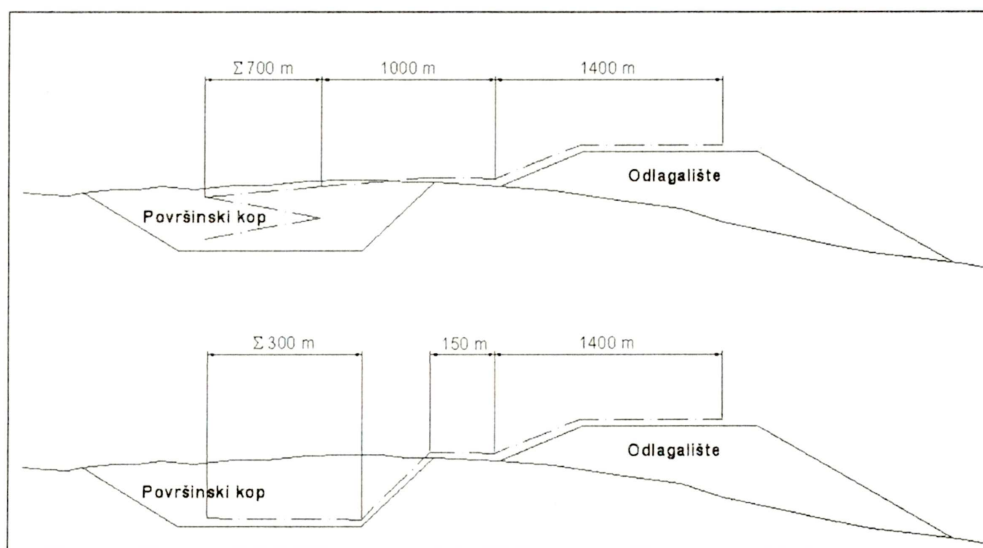


Figure 4 Shema of Truck Transport and Truck Lift System
slika 4 Šematski prikaz transporta kamionima i kombinovanim sistemom sa liftom

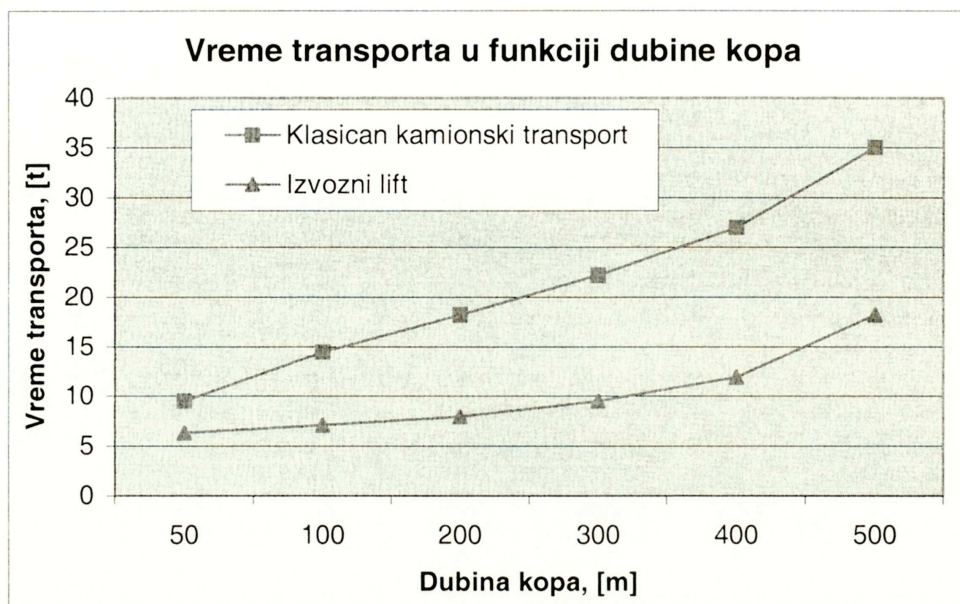


Figure 5 Results of Analises
slika 5 Rezultati analize

The results obtained demonstrate that as the conveying lengths, i.e. mine depths become larger or greater the advantages of combined conveyance /truck-elevator, become more obvious in conditions of opencast metal mining.

Certainly, it is necessary to emphasize here that this system yields significant economic effects that may not be neglected. In other words, the implementation of these conveyance systems enable considerable reduction of investments such as, investment for purchasing and maintenance of new trucks, construction and maintenance of haulage roads, erection and maintenance of crushing plants and spreaders.

5 CONCLUSION

Bearing in mind all the previously stated advantages of inclined elevators in comparison to both conventional discontinuous conveyance by trucks and combined conveyance (truck-crusher-belt conveyor-spreader) it may be concluded that the implementation of this conveyance system in conditions of deep opencast metal mines will certainly be cost-effective.

Moreover, apart from the basic economic criterion this system also meets other important criteria such as safe and reliable operation, long lifetime, small maintenance costs etc.

Na osnovu dobijenih rezultata vidi se da sa porastom transportnih dužina, tj. sa povećanjem dubine kopa, značajne su prednosti kombinovanog transportnog sistema kamion-lift i u našim uslovima površinske eksploatacije mineralnih sirovina.

Svakako ovde se mora naglasiti da efekat koji nastaje smanjenjem investicionih ulaganja u nabavku novih kamiona i njihovo održavanje, izgradnju i održavanje transportnih puteva, izradu postavljanje i održavanje drobilničnih postrojenja, odlagača, nije ekonomski ni malo zanemarljiv.

5 ZAKLJUČAK

Imajući u vidu sve dobre osobine izvoznih liftova, nabrojane u radu, u odnosu na klasičan diskontinualni transport kamionima kao i u odnosu na kombinovani transport (kamion-drobilica-transporter-odlagač), njihova primena na dubokim kopovima metalnih mineralnih sirovina sigurno bi dovela do velikih ušteda pri eksploataciji.

Naime, pored osnovnog kriterijuma za izbor transportnog sistema - ekonomskog efekta, potrebno je zadovoljiti i druge kriterijume: pouzdan i siguran rad, dug životni vek, nisku cenu održavanja i dr. Na osnovu prethodne analize može se zaključiti da ovi sistemi zadovoljavaju gotovo sve zadate kriterijume.

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