Arch. Min. Sci., Vol. 57 (2012), No 3, p. 779–785

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.2478/v10267-012-0050-1

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SELECTION OF ORE TRANSPORT SYSTEM FOR A METALLIFEROUS UNDERGROUND MINE

DOBÓR SYSTEMU TRANSPORTU RUD W KOPALNI PODZIEMNEJ RUD METALU

The conditions of increasing competition in today's mining industry, deepening of mines and also decreasing ore reserve and quality parameters (grade, calorie, ppm, etc.) compels to reduce unit cost for maximum benefit. In this context, optimization of machinery and equipment in technical and economical sense is required in terms of economic mining. In underground mining, as ore transport operation significantly affects profitability, optimization of the system gains importance technically and economically. In this paper, the authors studied production capacities up to 1,000,000 ton/year and orebody depths up to 1,000 m according to different haulage systems; conventional shaft hoisting, declined mine truck haulage and flexowell vertical belt applications. In model study, unit transport costs of each alternative depending on the production capacity and mine depth have been calculated.

Keywords: Shaft hoisting; Ramp haulage; Vertical conveyor; Underground ore transport system

Rosnąca konkurencja w sektorze wydobywczym, pogłębianie szybów, wyczerpywanie się zasobów rud i obniżanie ich parametrów jakościowych (zawartość metalu w rudzie, kaloryczność, ppm) zmuszają do wysiłków na rzecz maksymalnego ograniczania kosztów jednostkowych i maksymalizacji korzyści. W tym kontekście w działalności przedsiębiorstwa wydobywczego konieczna jest optymalizacja użytkowania maszyn i sprzętu i myślenie ekonomiczne. W kopalniach podziemnych systemy transportowania rud w znacznym stopniu wpływają na poziom rentowności, tak więc optymalizacja tych systemów zyskuje na znaczeniu, zarówno w aspekcie ekonomicznym jak i technicznym. W pracy tej autorzy analizują działanie kopalni o możliwości produkcyjnej do 1 000 000 ton rocznie, o głębokości szybów do 1 000 m przy zastosowaniu różnych systemów transportowania urobku: typowych wyciągów górniczych, transportu przy pomocy pojazdów kopalnianych oraz transport pionowym przewodem. W badaniach modelowych uwzględniono koszty transportu dla każdej z wymienionych opcji, w zależności od możliwości produkcyjnych zakładu i głębokości szybu.

Słowa kluczowe: wyciąg górniczy, pomost, przenośnik pionowy, system transportu w kopalni podziemnej

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1. Introduction

The ore transport item that forms the majority of cost in underground mines affects the overall profitability of the mine significantly. For this reason, many alternative transport systems and the eligibility of the machinery-equipment technically and economically are of great importance.

Ore transport method selection is directly related to applied underground mining method. For example, caving stope methods especially block / panel caving will likely enable the operations as an underground method to continue achieving a high production rate and low costs (Bakhtavar et al., 2009). Important factors affecting the choice of ore transport method can be summarized as ore reserve, production capacity, underground mining method, ground conditions, thickness, depth and dip of orebody, planned mine life, development schedule, price of selected machine-equipment, amortization and discount rate.

Among these criteria, especially production rate and mine depth are important factors (McCarthy, 1999). Advances in trucking technology in recent years have extended the depth of changeover from truck haulage to shaft hoisting. For many small and medium-sized mines, ramp haulage by trucks seems to be the most suitable economic method with low investment cost. For example, two-thirds of Australia's underground mines have chosen a ramp-truck haulage system (Chadwıck, 2000). However, the increase in mine depth and production capacity, despite the high initial investment, puts forward the shaft hoisting with low operating costs.

The optimum changeover depth from declined haulage to shaft hoisting becomes shallower as production rate increases (McCarthy & Livingstone, 1993). In good ground, at production rates less than one million tons per year, truck haulage on a decline (ramp) is a viable alternative to shaft hoisting to depths of at least 300 m (Northcote & Barnes, 1973). New mines less than 300 m depth and less than 400,000 tpa then decline only (Moser, 1997). Small sized deposits may be most economically served by ramp and truck haulage to a vertical depth of as much as 500 m. A medium-sized deposit, say 4 million (short) tons, may be most economically served by ramp and truck haulage to a vertical depth of 250 m (De La Vergne, 2003). The break-even depth is somewhere 300 to 400 m range, depending on conditions (Hustrulid and Bullock, 2001). Hall (2005) has studied on a methodology for investigating the shaft versus trucks decision. He has studied to identify the latest date at which the decision to sink a shaft can be made, after which time the shaft option will not be economic (Hall, 2005).

A flow sheet evaluated with numerical values for alternative transport system has been given in Fig. 1. For the orebodies with shallow overburden, mine depth up to 300 m and production capacity up to 2,500 ton/day, ramp haulage can be preferred (De La Vergne, 2003). For deeper mines with high production capacity inclined belt conveyor and shaft hoisting seems to be the most alternative.

2. Model study

Criteria for selection of suitable alternatives must require minimum amount of investment, also minimize ore transportation costs and must be easy to be implemented and operated (Elevli et al., 2002). In model study, unit transport costs for alternative underground ore transport for increasing mine depth and production capacities, three different transport systems and their unit transport costs have been calculated.

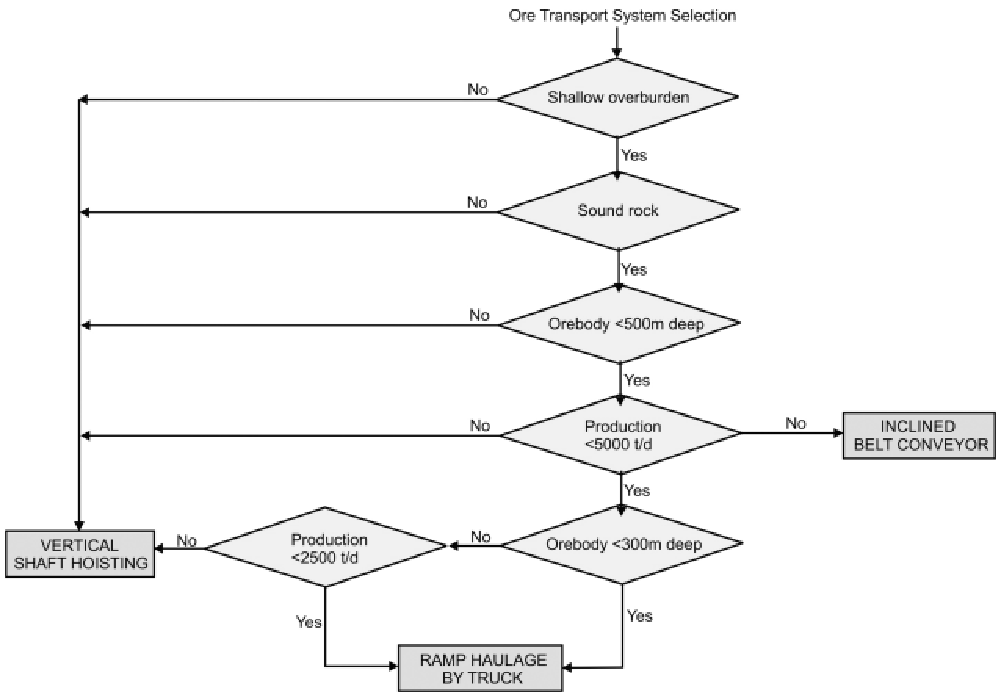

Fig. 1. Comparison of alternative transport systems (De La Vergne, 2003)

Flexowell belts are manufactured with flexible lateral sidewalls. The flexibility of the sidewalls is necessary for the belt to wrap around the drive and bend pulleys. For steeply inclined or vertical conveying, the belts are provided with transverse cleats (Grabner & Franz, 1997). Flexowell vertical belt conveyor is cost-effective, requires low maintenance, with reduced power consumption, high performance and long service life (Paelke et el., 2006). In Turkey at Asikoy Kure underground copper mine world's one of the longest flexowell vertical belt conveyor has been established in 140 m length. The ore coming from ore pass, crushed to -10 cm and travels along a conveyor belt to a feeder and then into flexowell vertical belt conveyor system (Gonen, 2011).

In case of ore transportation with shaft hoisting, shaft diameter 6 m, maintenance and spare part 5 % of total investment is accepted. Interest ratio is 10 %. Optimum rope speed, hoist drum diameter, total installed horsepower, headframe size and headframe height values and related investment costs are determined by equations with the help of SME mining engineering handbook cost estimation chapter (Cummins et el., 1996).

For vertical conveyor; shaft diameter has been selected smaller (3,8 m). Maintenance and spare part amounts are accepted as 5 % of total investment. Interest ratio is 10 %. Flexowell unit cost has been accepted as 6.000 $/m. By looking at the applications of vertical belt conveyor and producer company catalogues, they were assumed not to be employed at depths after than 250 m.

For ramp haulage, 20 ton capacity trucks with unit price of 700,000 $ has been selected. Spiral ramp grade with 10 %, hourly fuel consumption 29 lt, truck box-loaded speed 10 km/h, box-empty speed 20 km/h are accepted.

3. Evaluation of alternative transport systems

Unit transportation costs of shaft hosting, ramp haulage and vertical belt conveyor systems are calculated for different production capacities and mine depths (Table 1). For different operating depths and capacities where the unit transport costs are equalized, the critical value at, which the system loses its economical value, is found.

TABLE 1

Unit costs of transport systems for various production capacity and mine depth ($/ton)

	SHAFT HOISTING						VERTICAL BELT CONVEYOR						RAMP HAULAGE					
	Production capacity (ton/year)						Production capacity (ton/year)						Production capacity (ton/year)					
Mine depth (m)	200,000	300,000	400,000	600,000	800,000	1,000,000	200,000	300,000	400,000	600,000	800,000	1,000,000	200,000	300,000	400,000	600,000	800,000	1,000,000
50	3.79	2.82	2.32	1.81	1.56	1.41	2.98	1.98	1.49	0.99	0.74	0.60	1.94	1.64	1.49	1.34	1.26	1.22
100	5.02	3.73	3.07	2.40	2.07	1.87	4.33	2.89	2.16	1.44	1.08	0.87	3.06	2.53	2.26	1.99	1.86	1.78
150	6.19	4.58	3.76	2.93	2.52	2.27	5.69	3.80	2.85	1.90	1.42	1.14	4.18	3.41	3.03	2.65	2.46	2.34
200	7.34	5.40	4.42	3.44	2.95	2.65	7.07	4.72	3.54	2.36	1.77	1.42	5.30	4.30	3.80	3.31	3.06	2.91
250	8.48	6.22	5.07	3.93	3.35	3.01	8.46	5.64	4.23	2.82	2.12	1.69	6.42	5.19	4.58	3.96	3.66	3.47
300	9.61	7.02	5.71	4.41	3.75	3.36	Technically not suitable						7.54	6.08	5.35	4.62	4.25	4.04
400	11.86	8.61	6.98	5.34	4.52	4.04							9.78	7.85	6.89	5.93	5.45	5.16
500	14.09	10.18	8.22	6.25	5.28	4.69							12.02	9.63	8.44	7.24	6.65	6.29
600	16.33	11.75	9.45	7.16	6.01	5.33							14.26	11.41	9.98	8.56	7.84	7.42
800	20.80	14.87	11.90	8.93	7.46	6.58							18.74	14.96	13.07	11.18	10.24	9.67
1,000	25.27	17.98	14.33	10.70	8.88	7.81							23.22	18.51	16.16	13.80	12.63	11.92

In Table 2, changeover depth and production rate from ramp haulage to vertical conveyor and have been given. As seen from the table, at 360,000 ton/year production capacity, changeover point from ramp haulage to vertical conveyor is at 160 m mine depth. Over 360,000 ton/year production capacity at 160 m mine depth ore transportation with vertical belt conveyor becomes the most economical system.

TABLE 2

Changeover depth and production rate from ramp haulage to vertical conveyor

Production capacity (ton/year)	**Mine depth (m)**
350,000	250
360,000	160
385,000	75
400,000	50
425,000	25
440,000	10

In Table 3, changeover depth and production rate from ramp haulage to shaft hoisting have been given. At 400,000 ton/year production capacity, changeover point from ramp haulage to shaft hoisting is on 425 m mine depth. Over 400,000 ton/year production capacity at 425 m mine depth, ore transportation with shaft hoisting becomes the most economical system.

TABLE 3

Changeover depth and production rate from ramp haulage to shaft hoisting

Production capacity (ton/year)	**Mine depth (m)**
300,000	750
400,000	425
600,000	250
800,000	165
1,000,000	130

With increasing production capacity and mine depth shaft hoisting becomes the more economical system. While for 400,000 ton/year production capacity, ramp haulage is economic until 425 m mine depth, for 1,000,000 ton/year production capacity, economic mine depth for ramp haulage declines to 130 m. For lower production capacities, with its low investment cost ramp haulage should be preferred. With increasing production capacity and mine depth, ramp haulage completely loses its economic viability. For higher production capacities with lower mine depth especially under 250 m, vertical conveyor seems to be the most economic transport system which is the technical applicability boundary for vertical conveyor systems.

4. Result and discussion

The graph in Fig. 2. has been composed by using the values (Table 2, 3) of various transport alternatives for changing production capacities. As seen from the graph given below;

- Generally, for all operating depths, ramp haulage is economical up to a capacity of 300,000 tons per year.
- At high production capacities, especially until the boundary value of 250 m, vertical belt conveyor system seems more economical due to low initial investment and amortization.
- For high capacity and deep mines, the shaft hoisting is the most predominant system.

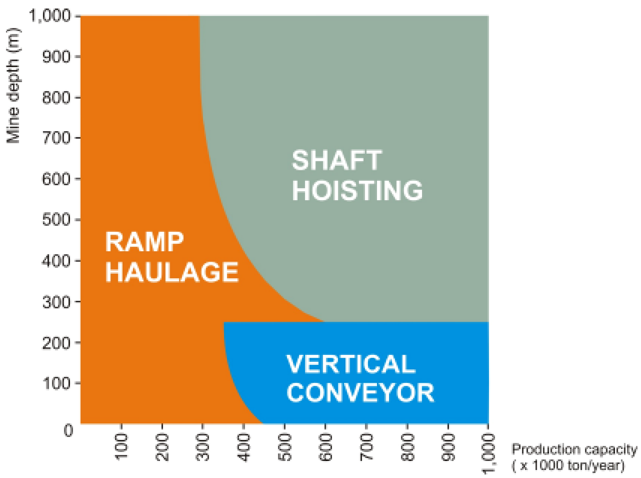

Fig. 2. Underground ore transport system selection using production capacity and mine depth

5. Conclusions

The ramp haulage appears to be economical in mines whose production capacity is under 300,000 tons/year owing to low amortization and initial investment costs for all operating depths. The vertical band conveyor is technically ideal until a maximum depth of 250 m for medium-high production capacities. The shaft hoisting is an imminent method especially for deep and high-capacity mines as the initial investment cost is much. In order to derive more realistic and definite results, optimal solutions should be developed by taking into consideration the economic lifetimes of selected machinery-equipment and the net present value at dynamic conditions.

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Received: 09 August 2011