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METHODOLOGY FOR CHOICE AN OPTIMAL BELT CONVEYOR IN UNDERGROUND MINES

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ABSTRACT
The paper presents a methodology for optimal belt conveyor selection for underground haulage in main levels in mines. It's based on the minimum specific costs necessary for transportation of run of mine ore.

Key words: *belt conveyor, methodology, specific transportation costs*

ABSTRAKT
Во трудот е прикажана една методологија за избор на оптимален лентест транспортер во главните транспортни ходници во рудниците. Таа е заснована на минималните специфични трошоци неопходни за транспорт на ровната руда.

Клучни зборови: *лентест транспортер, методологија, специфични транспортни трошоци*

1. INTRODUCTION

Information technology fast development and computer application in mining industry made the old fashion approach for transportation system selection to be completely abandoned.

This approach was based on simple evaluation for single transportation system in real conditions, without taking in account large number of technically possible options and choosing the one with lowest specific transportation costs per ton ore. The possibility of today computers to memorize huge number of data, allow development of new approach for transportation system selection. With this approach a time consuming calculations are made in a few seconds with increased precision.

The paper presents a methodology for optimal belt conveyors selection in main transportation drifts in hard rock underground mines, based on this modern approach.

2.METHODOLOGY FOR OPTIMAL BELT CONVEYOR SELECTION

A methodology for optimal belt conveyor selection in underground drifts is consisted of two consecutive analyses:

- Technical evaluation, in which rationalization of belt conveyors is performed based on their technical parameters,

- Economical evaluation, where rational solutions are compared by the specific costs, expressed as $/ton.

2.1 Belt conveyors technical evaluation

The fig. 1 shows the block chart for belt conveyors technical analysis. The chart is consisted of 5 blocks.

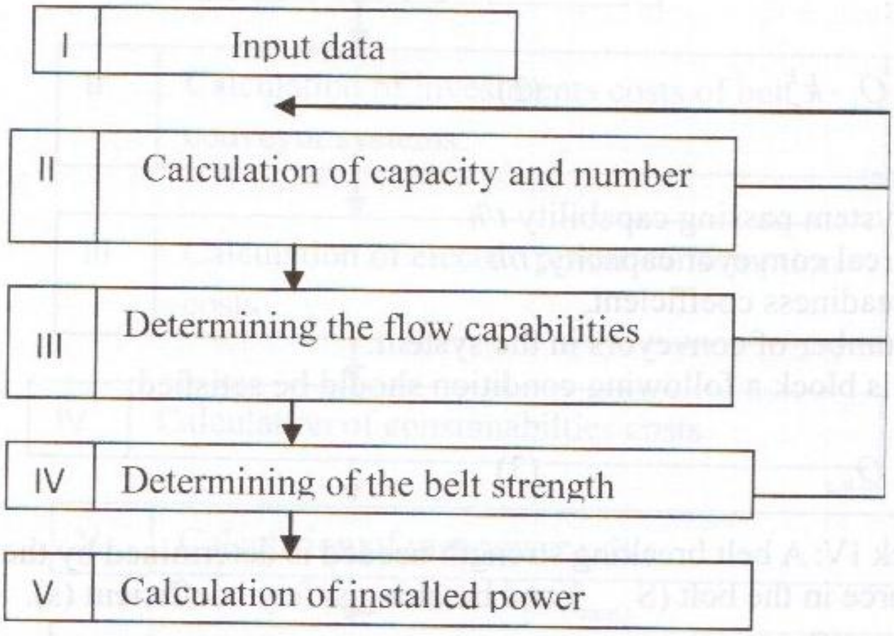

Fig. 1. Block diagram for technical analysis of belt conveyors

Block I: Input data for the modeling

Q_g - annual ore production, *t*
L - drift length, *m*
α - drift average inclination, *grades*
v - belt speed, *m/s*
k_1 - capacity reserve coefficient,
γ_r - volumetric bulk ore mass, *t/m³*
T - transportation system lifetime, *years*
z - number of working days per year, *days*
n_s - number of working shifts per day,
t_s - effective working hours per shift, *h*

Block II: In this block transportation capacity is calculated and compared with production capacity:

$$Q_1 \geq Q_{h,z} \qquad (1)$$

Q_1 – real belt conveyor capacity per hour, *t/h*

$Q_{h,z}$ - production capacity given, *t/h*.

Transportation length and belts braking strength give number of conveyors in the system.

Block III: A product of real belt conveyor capacity and coefficients expressing possibilities of achieving this capacity is defined as system passing capability:

$$P = Q_1 \cdot k_r^k \qquad (2)$$

where:

P - system passing capability *t/h*

Q_l - real conveyor capacity, *t/h*

k_r - readiness coefficient,

k - number of conveyors in the system.

In this block a following condition should be satisfied:

$$P \geq Q_{h,z} \qquad (3)$$

Block IV: A belt breaking strength needed is determined by the minimum tension force in the belt ($S_{n,max}$) and breaking safety coefficient (s).

$$K_{n,p} = \frac{S_{n,\max}}{B} \cdot s \text{ ,kN/m} \qquad (4)$$

B -belt width, *m*

A belt breaking strength needed, derived from the equation above should be smaller than the braking strength given by the manufacturer.

$$K_{n,p} \leq K_n \qquad (5)$$

K_n – belt nominal breaking strength, *kN/m*.

In cases where breaking strength of the belts from the database doesn't match, than the number of the conveyors in the system is increased.

Block V: Electric power of the conveyors driving motors is calculated by the following equitation:

$$N_1 = \frac{W_c \cdot v}{1000 \cdot \eta} \text{, kW} \qquad (6)$$

W_c - total resistance of belt moving, *N*

v - belt speed, *m/s*

η - total transmission efficiency.

2.2. Belt conveyors economic evaluation

A block chart describes the economic evaluation of the belt conveyors in nderground mines is shown at Figure 2. The results obtained from the techni-l evaluation represent the input data for economical evaluation of belt con-eyors.

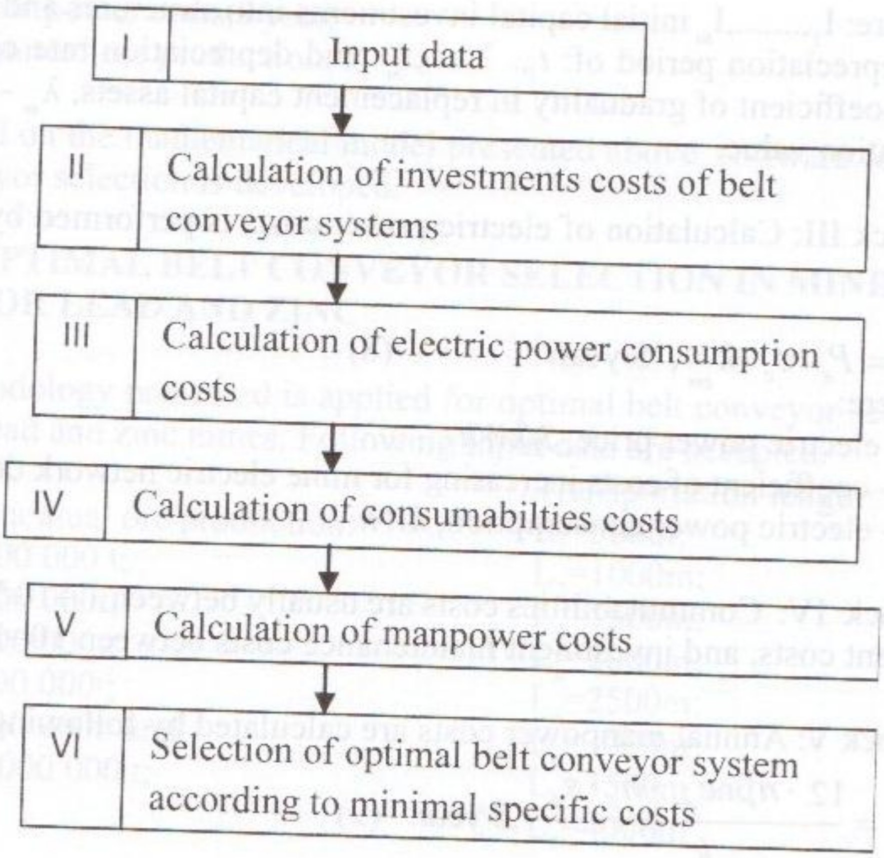

Fig. 2 Economic evaluation block for optimal belt conveyors selection

Block I. Input data for economic evaluation

c_{ba} - pulley prices, *\$*
c_{gv} - carry idlers prices, *\$*
c_{dv} - return idler prices, *\$*
c_{le} - belt price per unit length, *\$/m*
c_{rp} - drifting costs per unit length, *\$/m*
c_{el} - motor price per kW installed power, *\$/kW*
c_{rl} - transmission price per unit of torque, *\$/Nm*
c_{nk} - support price per unit length, *\$/m*
s - interests rate, %
e_5 - electric power price, *\$/kWh*

p_b - average monthly costs per employ, *\$/month*

Block II: Calculation of annual costs of investments:

$$A=\sum_{1}^{m} I_m \cdot \alpha_m \cdot e_m \cdot \lambda_m \text{ ,\$/year} \quad (7)$$

where: I_1,.......,I_m initial capital investments into structures and equipment with a depreciation period of: t_1,.........,t_m and depreciation rate of: α_1,........ α_m. e_m - coefficient of graduality in replacement capital assets, λ_m - coefficient of liquidation value.

Block III: Calculation of electric power costs is performed by following equation:

$$T_e = P_e \cdot c_e \cdot k_{em} \text{, \$/year.} \quad (8)$$

where:

c_e - electric power price, *\$/kWh*

k_{em} - coefficient of costs increasing for mine electric network development,

P_e - electric power consumption, *kWh*.

Block IV: Commutabilities costs are usually between 1 ÷10 % from total investment costs, and investment maintenance costs between 10÷15%.

Block V: Annual manpower costs are calculated by following equation:

$$T_r = \frac{12 \cdot n_r \cdot c_{pr} \cdot n_s \cdot s_d}{k_{rv}} \text{ ,\$/year} \quad (9)$$

where:

n_r - number personnel needed for normal functioning of the transportation system,

c_{pr} - average net payment per worker, *\$/monthly*

n_s - number of working shifts per day,

s_d - tax rate per net payment,

K_{rv} - coefficient of available annual working time usage.

Block VI: Here an optimal transportation system is selected, based on minimal specific transportation costs per ton of ore. Target function is:

$$c = \frac{A + I_{io} + T_e + T_{to} + T_m + T_r}{Q_g} \rightarrow Min, \ \$t \quad (10)$$

where:

A - annual value of depreciation, *\$/year,*
T_{io} - costs of investments maintenance and assurance, *\$/year,*
T_e - consumed electricity costs, *\$/year,*
T_{to} - maintenance costs, *\$/year,*
T_m - commutabilities costs, *\$/year,*
T_r - manpower costs, *\$/year,*
Q_g - annual ore production, *t.*

Based on the mathematical model presented above, software for optimal belt conveyor selection is developed.

3.0 OPTIMAL BELT CONVEYOR SELECTION IN MINES FOR LEAD AND ZINC

Methodology presented is applied for optimal belt conveyor selection in domestic lead and zinc mines. Following input data are accepted.

- Mines annual ore production:
  Q_{g1}=500 000 t;
  Q_{g2}=600 000t;
  Q_{g3}=700 000t;
  Q_{g4}=800 000t;
  Q_{g5}=900 000t and
  Q_{g6}=1 000 000 t;
- Transportation length:
  L_1=500m;
  L_2=1000m;
  L_3=1500m;
  L_4=2000m;
  L_5=2500m;
  L_6=3000m;
  L_7=3500m and
  L_8=4000m
- belt speed:
  v_1=1.32m/s;
  v_2=1.70m/s and
  v_3=2.12m/s
- average inclination of transportation drift:
  $\alpha = -0.2°$
- volumetric bulk ore mass:
  γ_r =2 t/m^3

Based on the results obtained from the software, following charts (fig.3 and 4) are prepared.

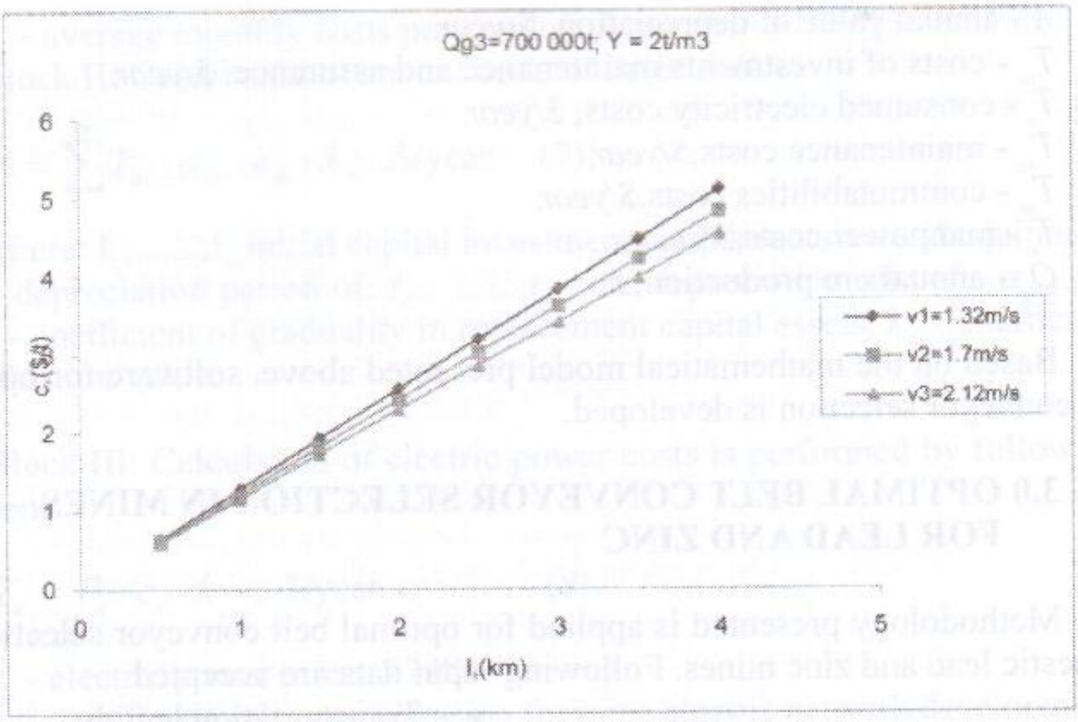

***Fig.3** Specific transportation costs per per transportation length*

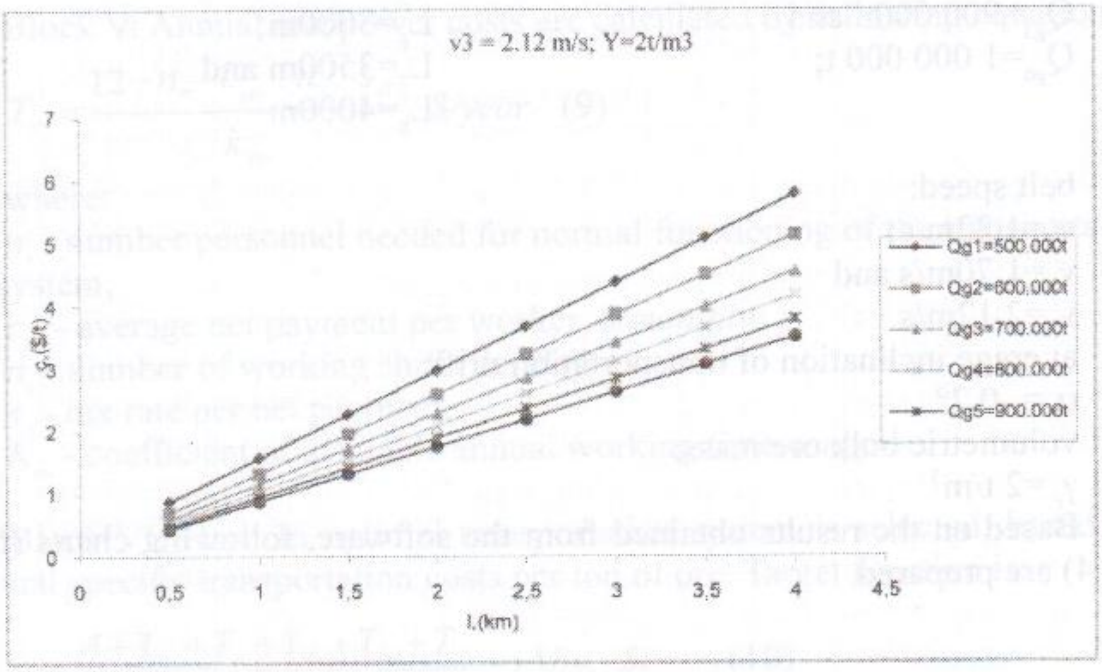

***Fig. 4.** Specific transportation costs per transportation length for different production capacities*

4. CONCLUSIONS

On the based of the results obtained, it was concluded that for domestic underground lead and zinc mines, an optimal solution is usage of two following belt conveyors.

- Conveyors with belt width of 800mm, breaking strength of 1000 ÷ 1400kN/m, belt speed 2.12m/s and following transportation length intervals and required power for annual ore productions given in table 1;
- Conveyors with belt width of 1000mm, breaking strength of 1400 ÷ 2500kN/m, belt speed 2.12m/s and following transportation length intervals and required power for annual ore productions given in table 2.

Table. 1

Qg(t/g)	500 000	600 000	700 000	800 000	900 000	1 000 000
L(m)	500 ÷ 3500	500 ÷ 3000	500 ÷ 3000	500 ÷ 2500	500 ÷ 2500	500 ÷ 2500
N(kW)	33 ÷ 193	36 ÷ 175	38 ÷ 190	40 ÷ 167	43 ÷ 176	45 ÷ 188

Table. 2

Qg(t/g)	500 000	600 000	700 000	800 000	900 000	1 000 000
L(m)	4000	3500÷ 4000	3500÷ 4000	3000 ÷ 4000	3000÷ 4000	3000 ÷ 4000
N(kW)	282	240 ÷309	275 ÷323	230 ÷338	241÷352	271 ÷366

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