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HAULAGE SOLUTIONS WITH TROLLEY ASSIST DIESEL-ELECTRIC AC TRUCKS ON THE PIT MINE RMU BANOVICI

Samir Nurić[#], Adila Nurić and Muhidin Brčaninović

University of Tuzla, Mining, Geology and Faculty of Civil Engineering, Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina

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Abstract

This paper reviews analysis possibility and advantages of application trolley assist diesel-electric AC (alternating current) trucks for hauling on the pit mines of black coal Banovići. Trolley assist is an option that saves diesel fuel by using overhead electrical power in place of the diesel engine for uphill hauls. Operating on trolley mode, the truck speed increase, depend on grade the reduction in fuel consumption is as high as 80 % for the trolley haul ramp and even to 50 % across the entire haulage network. Beside this, trolley assist has many other benefits. Analysis is performed for case application 254 t capacity Euclid-Hitachi EH4500 AC drive trucks.

Key words: *pit mine, trolley assist, AC trucks, stripping ratio, production cost.*

1. Introduction

Conventional shovel and truck mining operation is utilized at Grivice open pit at RMU Banovici since the mine started production. The pit bottom is about 100 m deep and features lengthy haul roads. Relative high and unstable price of fuel on world market has adverse tributary on cost of production. Continue of the coal production without changes in the present technology may cause serious economic consequences. Increasing limit of economic implementation transportation mass with truck can be made possible only application trolley drive on haul ramps [1]. It can be significant investigate all possibilities and depth of the pit mine with economic reasonable appliance loading-transportation complex shovel-diesel-electric AC trucks with provide power from overhead trolley lines [4].

2. Methodology executing of analysis

It is necessary designed the pit mine in few phase different depth with laying haul ramps with overhead lines for analysis application trolley assisted trucks. During design the pit mine essential stick to the pit geometry parameter defined with project documentation. Within drown

[#] ***Corresponding author:*** *snuric@yahoo.com*

contours the pit mine are calculated volume coal for excavation and overburden that should be removed. Estimation volume of coal and overburden is performed with combination bench maps and cross profiles [2]. Volumes by phase exploitation are presented in table 1.

Table 1. Volumes by phase exploitation

PHASE EXPLOATATION Σ	COAL R (Bm^3)	OVERBURDEN V (Bm^3)
I	7 606 350	54 437 610
II	13 452 063	115 945 448
III	12 978 801	180 995 581

Overall stripping ratio in first phase exploitation [2] (depth the pit mine 132 m):

$$K_{prI} = \frac{\sum V_I}{\sum R_I \cdot \rho_{c.m.}}, \ Bm^3/t \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$\rho_{c.m.}$ – density of coal (t/Bm^3)

$$K_{prI} = \frac{54\ 437\ 610}{7\ 606\ 350\ \cdot 1{,}38} = 5{,}19 \ Bm^3/t$$

Overall stripping ratio in second phase exploitation (depth the pit mine 216 m):

$$K_{prII} = \frac{\sum V_{II}}{\sum R_{II} \cdot \rho_{c.m.}}, \ Bm^3/t \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$K_{prII} = \frac{115\ 945\ 448}{13\ 452\ 063\ \cdot 1{,}38} = 6{,}25 \ Bm^3/t$$

Overall stripping ratio (first and second phase exploitation):

$$K_{pr} = \frac{\sum V_I + \sum V_{II}}{\left(\sum R_I + \sum R_{II}\right) \cdot \rho_{c.m.}}, \ Bm^3/t \ldots\ldots\ldots (3)$$

$$K_{pr} = \frac{54437610 + 115945448}{(7\,606350 + 13452063) \cdot 1{,}38} = 5{,}863 \ Bm^3/t$$

Overall stripping ratio in third phase exploitation (depth the pit mine 276 m):

$$K_{prIII} = \frac{\sum V_{III}}{\sum R_{III} \cdot \rho_{c.m.}}, \ Bm^3/t \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$K_{prIII} = \frac{180\ 995\ 581}{12\ 978\ 801\ \cdot 1{,}38} = 10{,}11 \ Bm^3/t$$

Overall stripping ratio (first, second and third phase exploitation):

$$K_{pr} = \frac{\sum V_I + \sum V_{II} + \sum V_{III}}{\left(\sum R_I + \sum R_{II} + \sum R_{III}\right) \cdot \rho_{c.m.}}, \ Bm^3/t \ldots\ldots\ldots (5)$$

$$K_{pr} = \frac{54437610 + 115945448 + 180995581}{(7\,606350 + 13452063 + 12978801) \cdot 1{,}38}$$

$$K_{pr} = \frac{351378639}{46971355{,}32} = 7{,}481 \ Bm^3/t$$

Instantaneous stripping ratio (K_d) is calculated on the end I, II and III phase development the pit mine for progress front mining works on the bench overburden and coal at one width of shovel block. Volumes of coal and overburden by phase's exploitation for calculation instantaneous stripping ratio are presented in table 2.

Table 2. Volumes of coal and overburden by phase's exploitation

VOLUMES FOR CALCULATION INSTANTANEOUS STRIPPING RATIO		
AT THE END	COAL R_d (Bm^3)	OVERBURDEN V_d (Bm^3)
I PHASE (DEPTH OF PIT MINE 132 m)	491 784	4 461 975
II PHASE (DEPTH OF PIT MINE 216 m)	703 965	8 007 175
III PHASE (DEPTH OF PIT MINE 276 m)	590 934	8 500 100

Instantaneous stripping ratio on the end first phases (depth of pit mine 132 m):

$$K_{dI} = \frac{\sum V_{dI}}{\sum R_{dI} \cdot \rho_{c.m.}}, Bm^3/t \ldots\ldots\ldots\ldots\ldots(6)$$

$$K_{dI} = \frac{4\,461\,975}{491\,784 \cdot 1{,}38} = 6{,}575 \text{ Bm}^3\text{/t}$$

Instantaneous stripping ratio on the end second phases (depth of pit mine 216 m):

$$K_{dII} = \frac{\sum V_{dII}}{\sum R_{dII} \cdot \rho_{c.m.}}, Bm^3/t \ldots\ldots\ldots\ldots\ldots(7)$$

$$K_{dII} = \frac{8\,007\,175}{703\,965 \cdot 1{,}38} = 8{,}242 \text{ Bm}^3\text{/t}$$

Instantaneous stripping ratio on the end third phases (depth of pit mine 276 m):

$$K_{dIII} = \frac{\sum V_{dIII}}{\sum R_{dIII} \cdot \rho_{c.m.}}, Bm^3/t \ldots\ldots\ldots\ldots\ldots(8)$$

$$K_{dIII} = \frac{8\,500\,100}{590\,934 \cdot 1{,}38} = 10{,}423 \text{ Bm}^3\text{/t}$$

For discussed production capacities determinate number elements cyclic load-hauling equipment fleet (shovels and trucks with pantographs). Number of shovels and trucks is calculated with and without mutually conditional waiting because is to take into account coefficient waiting (kc). Calculation parameters complex shovels and trolley assisted trucks accomplished with personally written program in programming language Fortran [3]. Flow chart is presented on figure 1 [6].

With calculated instantaneous stripping ratio (for defined phase development of the pit mine) multiply unit production cost by processes (drilling, blasting, digging, hauling and damping) [2]. Summation estimated values presenting expenses removing overburden by unit ore (coal). Those expenses are added unit cost production coal hence total value production is:

$$C_k = K_d \cdot C_o + C_u \quad (€/t) \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

K_d – instantaneous stripping ratio (Bm^3/t),
C_o – expenses removing overburden (€/Bm^3),
C_u – cost production coal (€/t).

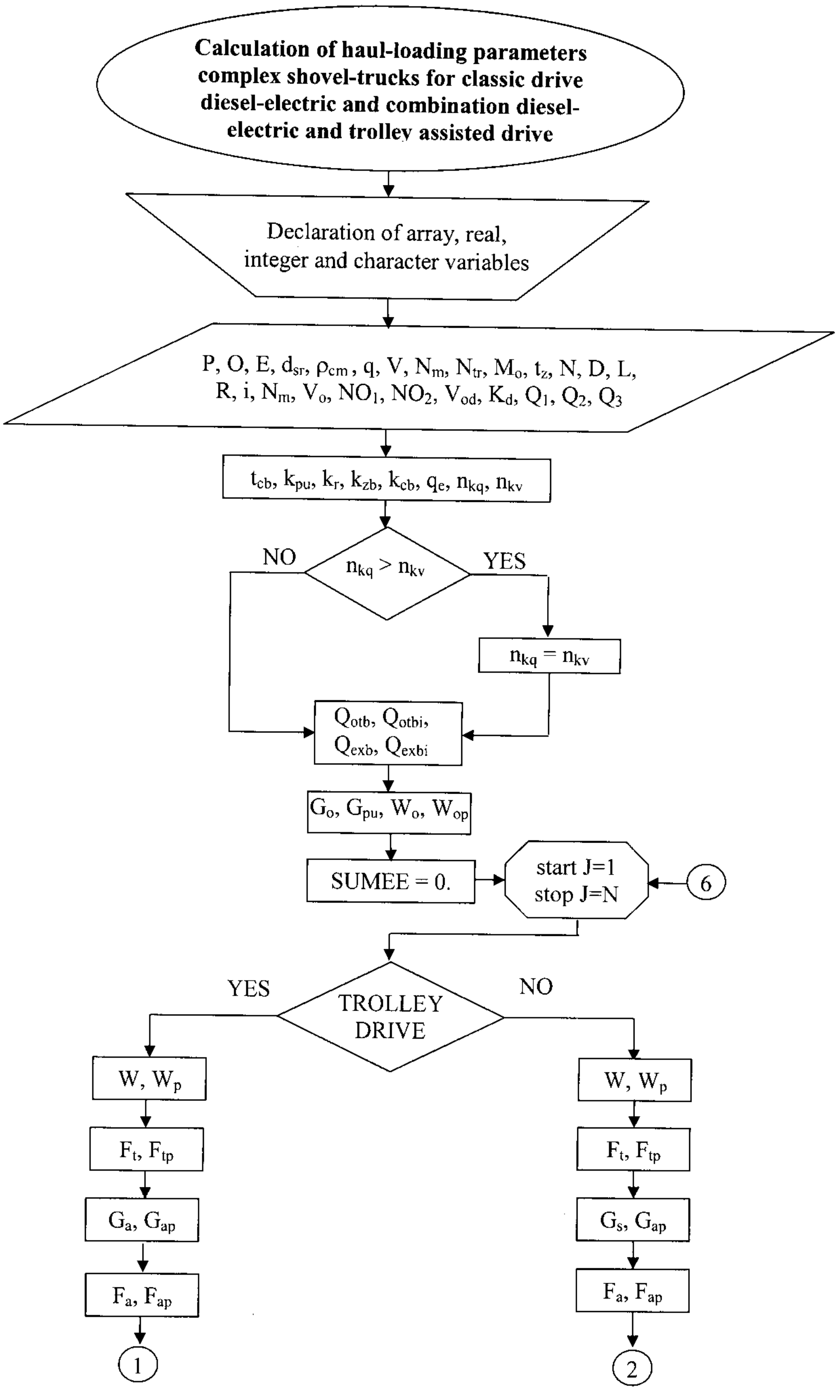

Figure 1a. Flow chart of calculation parameters complex shovels - trolley assisted trucks

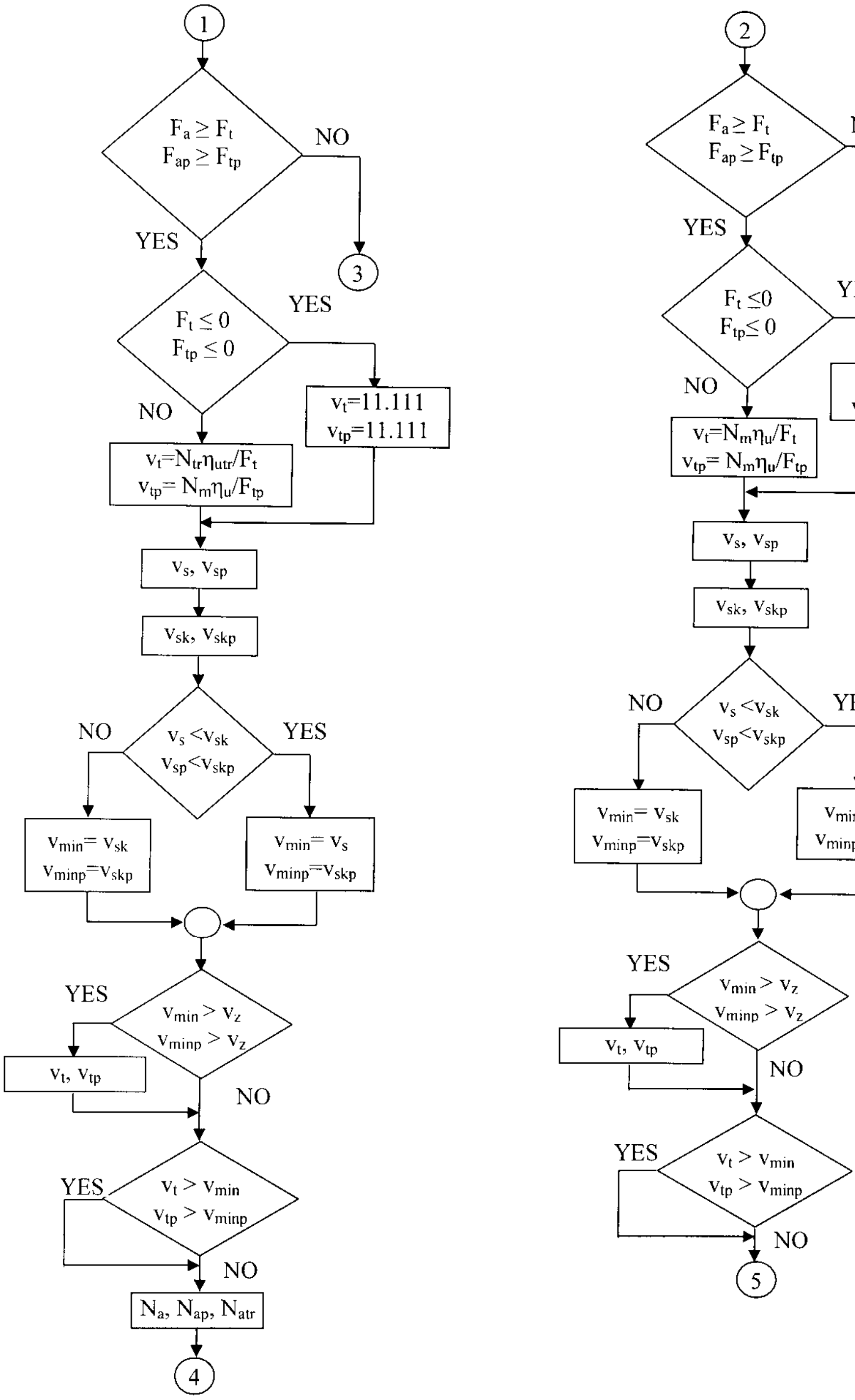

Figure 1b. Flow chart of calculation parameters complex shovels - trolley assisted trucks

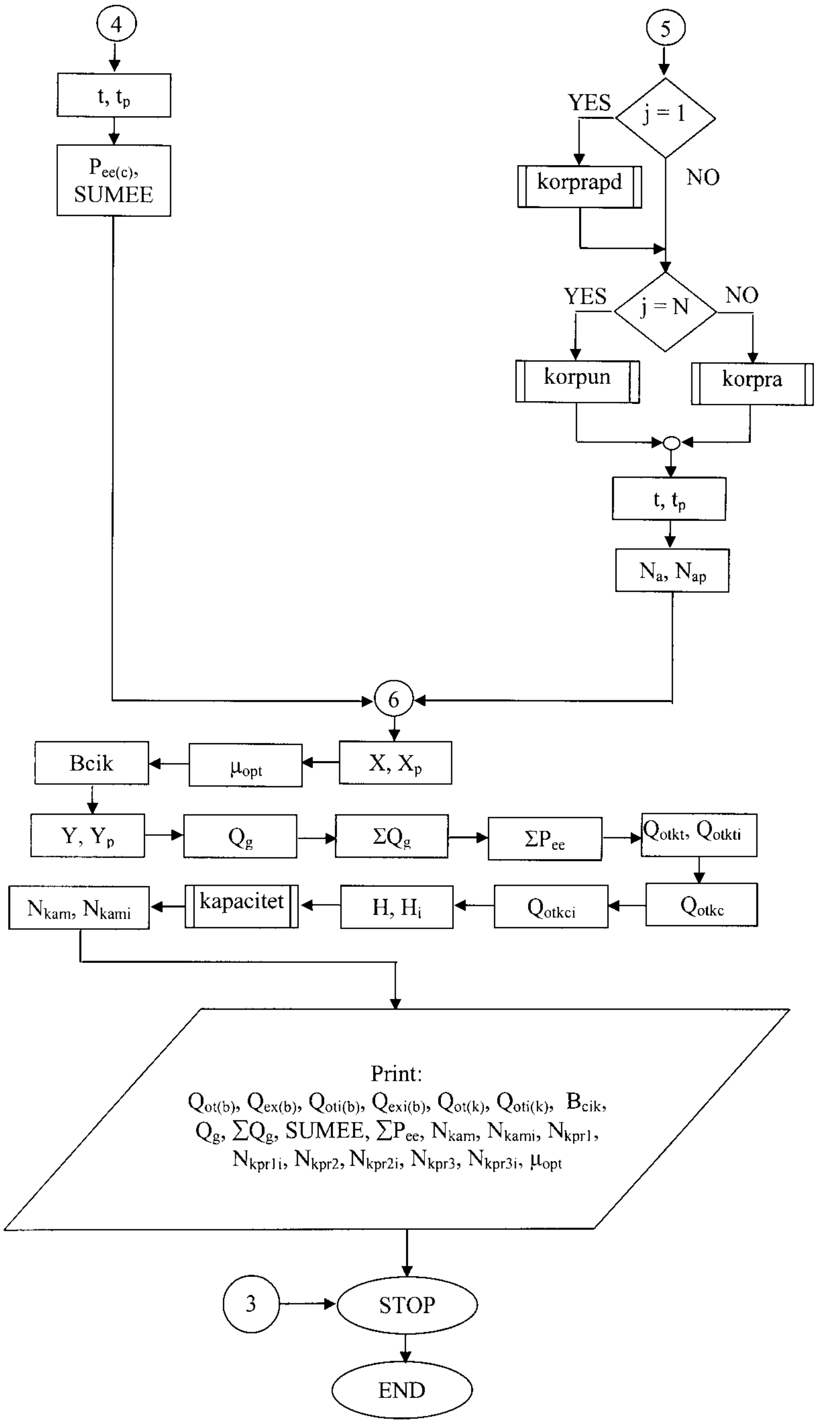

Figure 1c. Flow chart of calculation parameters complex shovels - trolley assisted trucks

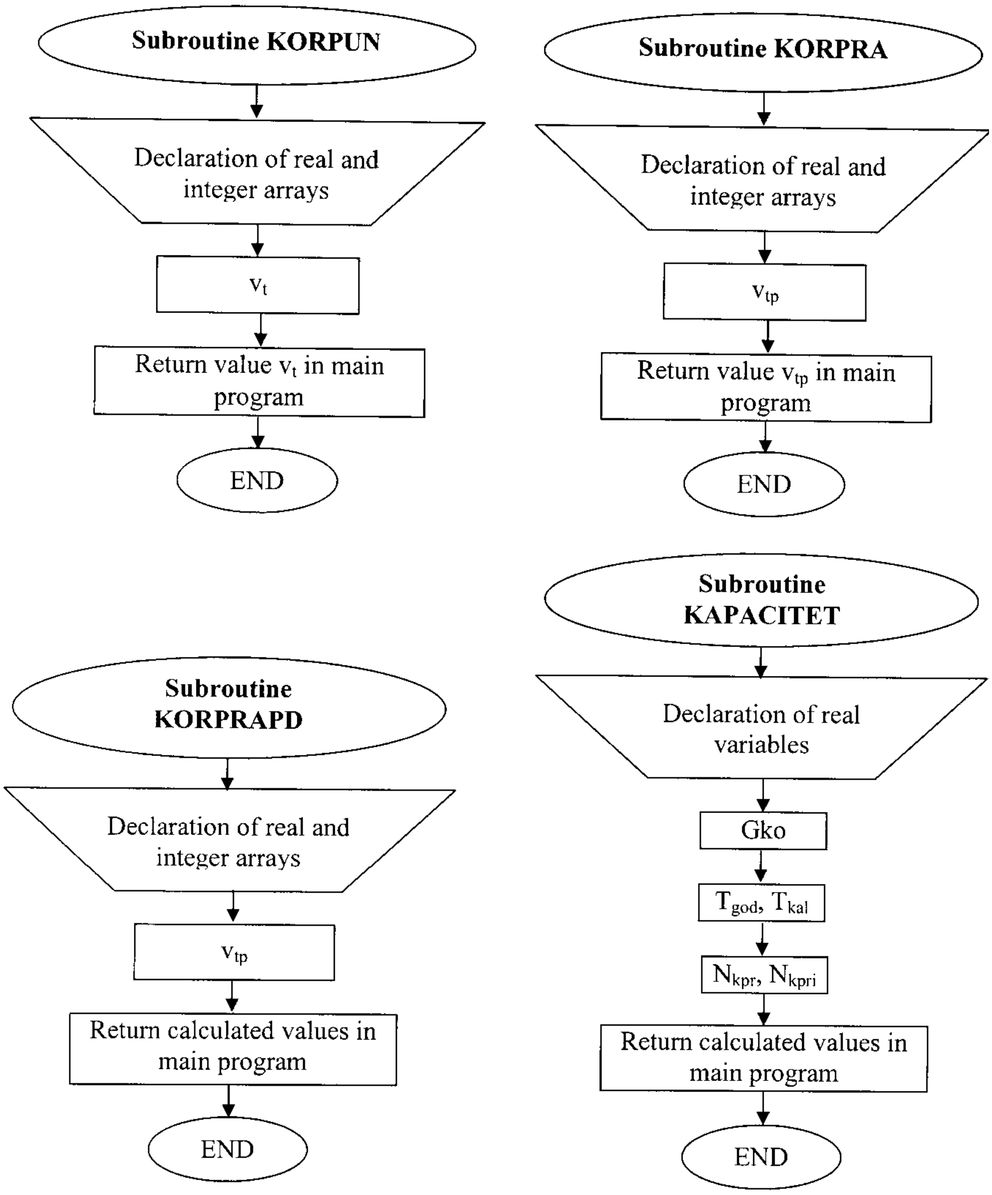

Figure 1d. Flow chart of calculation parameters complex shovels - trolley assisted trucks

3. Results and Discussion

The trucks higher speeds on haul ramps is results more powerful AC drives. On grade speed is limited by the available power. If the drive system can provide more power than the diesel engine, speed on grade increases proportional to power with a corresponding increase in productivity (to 20%) [4]. The trucks speed increases because the trolley line can supply more power than existing diesel engines on two AC traction wheel motors. For EH4500 that means two AC traction motors can reach 3600 kW instead 1900 kW [8]. The higher speed on trolley assisted mode means the shorter cycle transportation and higher productivity or fewer trucks for the same production. On the basis of the number of haul trucks, it is calculated finance investment in entire trolley system. The research showed that the use of trolley assist reduces fuel consumption between 45-60% depending on length trolley line. Reduction fuel consumption presented in table 3.

Table 3. Reduction fuel consumption presented

Phase exploatat.	Depth of pit mine (m)	Classic diesel-electric AC drive	Trolley assisted drive	
		Total consumption fuel for transportation instant. mass (l)	Total consumption fuel for transportation instant. mass (l)	Total consumption electr. power for transportation instantaneous mass (kWh)
I	132	7 564 852,76	4 033 284,99	7 114 372,20
II	216	15 441 628,06	7 020 850,20	17 602 476,63
II	276	19 568 080,50	8 132 834,98	23 920 944,98

Average energy value of coal on the pit mine Grivice RMU Banovici is 16,5 GJ/t. Results of performed techno-economic analysis are presented with diagrams production costs of 1 GJ of coal in function of depths pit [6]. All tests were examined in programming language Fortran [3], while data processing was done in Excel program.

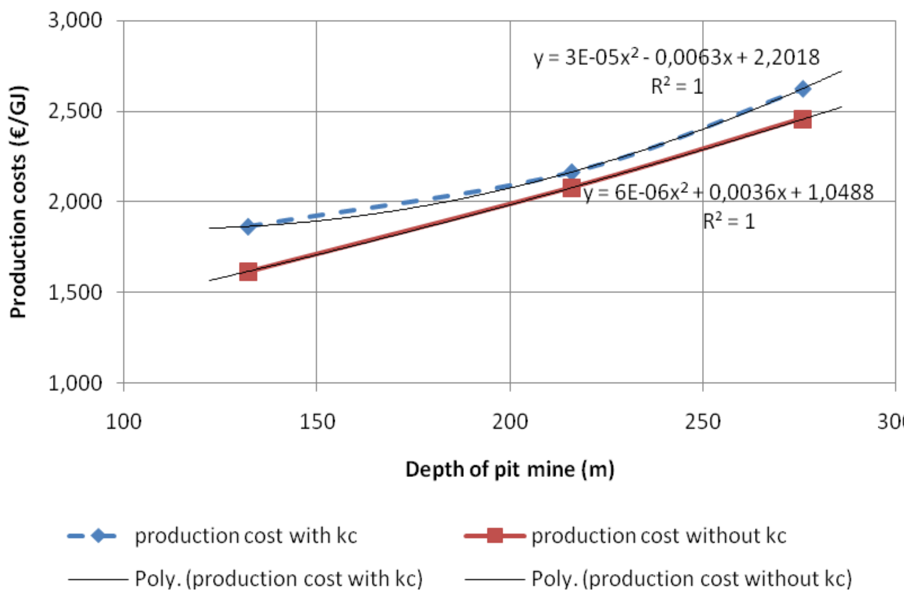

Figure 2. Production cost (€/GJ) depending on depth of pit mine (coal production 1 million t/y)

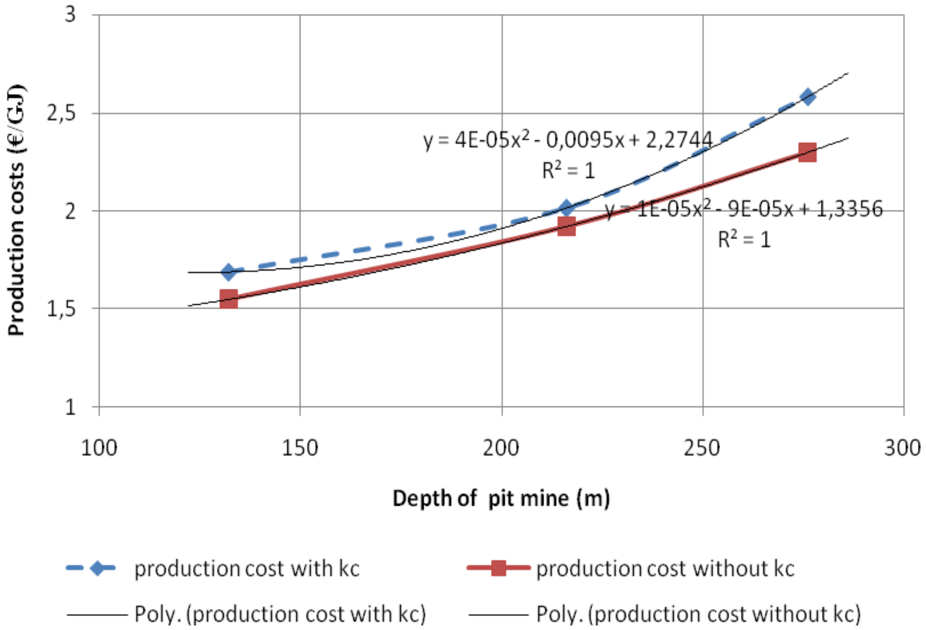

Figure 3. Production cost (€/GJ) depending on depth of pit mine (coal production 1.75 million t/y)

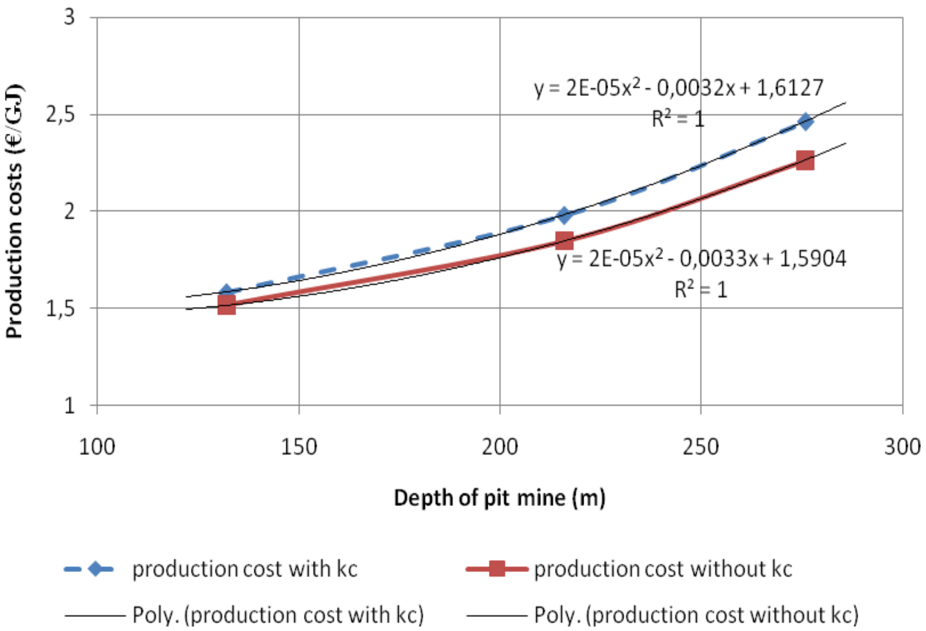

Figure 4. Production cost (€/GJ) depending on depth of pit mine (coal production 2.5 million t/y)

4. Conclusion

Finally, the analysis proved that there are benefits of applying trolley assist diesel-electric AC trucks on the open pit mine 'Grivice'. Providing other benefits trolley assist such as: extending intervals between engines overhauls, improves air quality by reducing diesel engine emissions, reduced noise etc. this trucks operation mode assigned like real need [5]. All these leading to the conclusion that for any pit mine deeper than 150 m, the possibility of installation trolley system should be seriously consider. Trolley assist can be an important aspect of Mine Black Coal Banovići economic success in recent years.

5. References

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