How Parameters of the Used Equipment Influence on Efficiency of Exploitation of Cyclic-Flow Technology Complexes

A V Glebov¹, A V Semenkin¹, G D Karmaev¹, V A Bersenev¹

¹ Federal State Budgetary Institution of Science, Institute of Mining, Ural Branch of Russian Academy of Sciences, Mamina-Sibiryaka St., 58, Ekaterinburg, 620219, Russia

E-mail: glebov@igduran.ru

Abstract. Influence of parameters of the used equipment on conditions of application of the cyclic-flow technology complexes (CFT) in comparison with an excavator and automobile complex (EAC) is considered in this article. Dependences of quantitative change of indicators of efficiency of application (a relative discounted specific expenses, a specific metal consumption, a specific power consumption, a labour productivity, assignments for air contamination) on height of rock formation's rising when using excavators with a volume of ladle from 5 to 20 cubic meters and dump trucks with a loading capacity from 45 to 130 tons in the CFT complexes are defined during the research. The preferable conditions of application of the CFT complexes with costs and without costs of a board rating when ore mining and overburden. As a result of realization of the research it is defined that in spite of the fact that using of more potent equipment influences on the quantitative value of indicators of effectiveness, the preferable conditions of application of the CFT complexes in comparison with EAC practically do not change.

1. Introduction
Cyclical-and-continuous technology (CCT) with vehicle-conveyor transport is a system characterized by parallel-and-sequential operation of equipment in adjacent links. The system approach to the selection of equipment for crushing-and-conveying complexes (CCC) and assembly vehicle transport determines the need to take into account the modes and mutual influence on the operation of the system of each link, including the extraction-and-loading equipment.

2. Actuality
The application of heavy-duty dump trucks in open-pit mines requires a large volume of excavation of overburden for construction of transport berms, hence, a large capital outlay. In spite of this, at the present time, in most of the ore and non-ore deposits of high productivity in Russia and abroad, mining equipment of large unit capacity is used to extract and transport rock mass. For example, Olenegorsky GOK with a capacity of 16 mln t/year uses dump trucks with a carrying capacity up to 136 tons and excavators with a bucket capacity of up to 12 m³ [1, 2], Kovdorsky GOK (16 mln t/year) uses dump trucks with a carrying capacity up to 136 tons and excavators with a bucket capacity up to 16 m³ [3, 2], Inguletsky GOK (capacity 34 mln t/year for ore) uses excavators with a bucket up to...
23 m³ and dump trucks with a carrying capacity up to 136 tons [2]. In connection with this, for more valid estimate of the preferred application conditions for the CCT complexes it seems advisable to determine the influence of the used equipment parameters on the operating efficiency of the CCT complexes in comparison with the EVC.

3. Scientific significance
A significant contribution to the study of cyclic-al-and-continuous technology has been made by many scientists such as: V. L. Yakovlev, M. V. Vasiliev, B. N. Tartakovsky, S. P. Reshetnyak, A. N. Shilin, B. A. Simkin, A. O. Spivakovskiy, G. D. Karmayev, V. S. Volotkovsky, V. A. Bersenev et al. [4-18]. However, most of the studies are intended to estimate the application of the CCT complexes at specific open-pit mines, as well as the application of various equipment in the structures of the complex mechanization. The existing works miss a uniform methodology for estimating the operating efficiency of the CCT complexes with the most accurate consideration of the operating mode of the crushing-and-conveying complex (CCC) and the joint consideration of the most significant criteria for estimation. On the basis of previous work, it is not possible to reasonably estimate the preferred conditions for the application of the CCT complexes, so the results of this study will increase the validity of the preferred conditions for their application.

4. Theoretical part
This study is intended to estimate the influence of the parameters of the equipment used in the CCT complexes on the preferable conditions of their application in comparison with the EVC. For the comparative version, the result obtained in [19] with some corrections has been taken as a basis. To estimate the operating efficiency of the CCT complexes in comparison with the EVK, the calculations have been made using the methods described in [19] and with the same mining technical factors.

At a capacity of 5 mln t/year, the author of [20] recommends to accept the same dump tracks as in the study [19] with a carrying capacity of 45 tons and excavators with a bucket capacity of 5 m³. At capacities of 10, 20, 30 mln t/year, dump trucks with a carrying capacity of 90, 130 and 130 tons and excavators with a bucket of 12, 15, 20 m³, respectively.

In the process of performing the work, according to the results of calculations, the dependence of the change in the operating efficiency indexes of the CCT complexes with more powerful equipment have been obtained. To estimate the influence of the parameters of the equipment used in the CCT complexes on the operating efficiency, the obtained dependences are shown graphically in Fig. 1 in comparison with the previously obtained results [19] (Fig. 2).

With the use of the CCT complexes, the accepted additional efficiency indicators such as the specific metal consumption, the specific energy intensity, the charges for air pollution, labor productivity have advantages in comparison with the EVC for all the mining and technical factors studied. According to the obtained dependencies, the preferred conditions for the use of the CCT complexes have been determined with and without consideration for the open-cut mining using excavators with a bucket capacity of 5 to 20 m³ and dump trucks with a carrying capacity from 45 to 130 t (Table 1, Table 2).

For example, when arranging the CCT complexes in the open-cut mining at a overburden capacity of 5 mln t/year and the height of lifting the rock mass of 180 m, their application is efficient in comparison with the EVC at relative discounted costs. At the height of lifting of 280-680 m at the same capacity, the CCT complex is not efficient. The CCT complex with a capacity of 30 mln t/year is more efficient than the EVC at the height of lifting of 180-580 m at relative discounted costs, at the height of 680 the costs differ insignificantly (up to 10%), the CCT is more efficient by specific metal consumption, specific energy intensity, labor productivity, charges for air pollution.

When arranging the CCT complexes in the open-pit mine practically without open-cut mining, their application is more efficient in comparison with EVC at relative discounted unit costs for all mining factors studied.
Figure 1. Change in relative discounted unit costs for the use of the overburden and ore CCT complexes and EVC depending on the height of lifting the rock mass at different capacities (with a lifting capacity of dump trucks of 45-130 tons, bucket capacity of an excavator from 5 to 20 m$^3$): a) With an annual capacity of 10 mln t/year. b) With an annual capacity of 30 mln t/year; $Z'$, $Z''$ are relative discounted unit costs when using EVC for ore development and overburden, respectively, %; $Zz$ are relative discounted unit costs when using the CCT, taking into account the cost of open-cut mining, %.

Figure 2. Change in relative discounted unit costs for the use of overburden and ore CCT complexes CCT and EVC depending on the height of lifting the rock mass at different capacities (with a lifting capacity of dump trucks of 45-130 tons, a bucket capacity of an excavator from 5 to 20 m$^3$): a) With an annual capacity of 10 mln t/year; b) With an annual capacity of 30 mln t/year.
Table 1. Preferred conditions for the use of the CCT complexes, taking into account the cost of open-cut mining using excavators with a bucket capacity from 5 to 20 m³ and dump trucks with a carrying capacity from 45 to 130 tons in comparison with the EVC.

Note: see Table 2.

| Type of transport material | Parameters of mining conditions | Indicators of estimation criteria | Estimation of efficiency |
|----------------------------|---------------------------------|----------------------------------|--------------------------|
| CCT complex | Overburden | Q, mln t/year | H, m | Zz-Z', % | Nz-N', W/t | Gz-G', kg/t | Pz-P', t/year | Sz-S', % | |
| 5 | 180 | -17.6 | -0.9 | 0 | 10673.3 | -64.9 | Efficient |
| 10 | 180-480 | -28.9-412.8 | -1.2-(-2.9) | -0.02-(-0.11) | 13286.9-15021.6 | -107.4-(-351.6) | Inefficient |
| 20 | 180-480 | -35.3-123.5 | -1.9-(-2.3) | -0.06-(-0.09) | 27410.4-26158.4 | -308.7-(-383.9) | Inefficient |
| 30 | 180-580 | -67.7-(-48) | -0.5-(-1.2) | -0.04-(-0.08) | 43501.6-47795.8 | -252.9-(-912.5) | Efficient |
| Ore | 5 | 180 | -41.2 | -1 | -0.07 | 10673.3 | -64.9 | Efficient |
| 10 | 180-480 | -65.6-(-38.8) | -0.7-(-1.8) | -0.06-(-0.12) | 26010.4-30657.4 | -77.6-(-248.1) | Efficient |
| 20 | 180-480 | -118.1-(-100.9) | -2.4-(-2.4) | -0.13-(-0.15) | 27410.4-26158.4 | -308.7-(-383.9) | Efficient |
| 30 | 180-580 | -124.5-(-186.3) | -0.8-(-2.4) | -0.06-(-0.13) | 28013.4-30091.3 | -176.7-(-816.3) | Efficient |
| 680 | -65.3-(-42.8) | -0.6 | -0.08 | 43501.6 | -252.9-(-912.5) | Efficient |
| 680 | -9.9 | -1.4 | -0.08 | -40261.1 | -1107.8 | Efficient |

The costs differ by no more than 10%. The application is more efficient by energy intensity, metal consumption, charges for atmospheric pollution and labor productivity.
Table 2. Preferred conditions for the application of the CCT complexes, taking into account the cost of open-cut mining using excavators with a bucket capacity from 5 to 20 m$^3$ and dump trucks with a carrying capacity from 45 to 130 tons in comparison with EVC.

Note: $Z_z$, $Z'$ are relative discounted costs when using the CCT complex and EVC, respectively, %; $N_z$, $N'$ are the specific energy intensity when using the CCT complex of and EVC, respectively, W/t; $G_z$, $G'$ are the specific metal consumption with the use of the CCT complex and EVC, respectively, kg/t; $P_z$, $P'$ are labor productivity with the use of the CCT complex and EVC, respectively, t/year; $S_z$, $S'$ are charges for air pollution in relative units using the CCT complex and EVC, respectively, %.

| Type of transport | Type of transported material | Parameters of mining conditions | Indicators of estimation criteria | Estimation of efficiency |
|-------------------|-----------------------------|---------------------------------|---------------------------------|-------------------------|
| CCT complex       | Overburden                  | Q, mln t/year; H, m             | $Z_z-Z'$, %; $N_z-N'$, W/t; $G_z-G'$, kg/t; $P_z-P'$, t/year; $S_z-S'$, % | Efficient |
|                   |                              | 5  180-680                      | -35.3(-94)  -0.9(-2.9)  0.0(-0.11)  10673.3-15021.6  -64.9(-351.6) | Efficient |
|                   |                              | 10 180-680                      | -50.9(-128.4)  -0.6(-2.3)  0.01(-0.09)  26010.4-26158.4  -77.6(-383.9) | Efficient |
|                   |                              | 20 180-680                      | -95.2(-247.1)  -0.7(-2.3)  -0.01(-0.07)  28013.4-30091.3  -176.7(-816.3) | Efficient |
|                   |                              | 30 180-680                      | -71.6(-92.1)  -0.7(-1.3)  -0.04(-0.05)  43501.6-40261.1  -252.9(-1107.8) | Efficient |
|                   | Ore                          | 5  180-680                      | -58.9(-118.5)  -1(-3)  -0.07(-0.18)  10673.3-15021.6  -64.9(-351.6) | Efficient |
|                   |                              | 10 180-680                      | -75.4(-151)  -0.7(-2.4)  -0.06(-0.15)  26010.4-26158.4  -77.6(-383.9) | Efficient |
|                   |                              | 20 180-680                      | -113.8(-270.6)  -0.8(-2.4)  -0.06(-0.13)  28013.4-30091.3  -176.7(-816.3) | Efficient |
|                   |                              | 30 180-680                      | -89.2(-111.8)  -0.6(-1.4)  -0.08(-0.08)  43501.6-40261.1  -252.9(-1107.8) | Efficient |
5. **Practical significance**

The results of the study allow to make a valid express estimate of the expediency for considering the CCT complexes at the design stage.

6. **Conclusion**

According to the results of the study, it has been established that the use of excavators with a bucket capacity of 5-20 m$^3$ and dump trucks with a carrying capacity of 45-130 tons in the CCT complexes in comparison with the operation in these complexes of less powerful equipment (excavators with a bucket capacity of 5-12 m$^3$, dump trucks with a carrying capacity of 45-90 t) has practically no effect on the preferred conditions for using the CCT complexes.

7. **References**

[1] [Network resource] Access mode: http://olcon.ru/

[2] Technical and Economic Indicators of Mining Enterprises for 1990-2013 2014 (Ekaterinburg: Institute of mining of Ural Branch of RAS) p 364

[3] [Network resource] Access mode: https://pikabu.ru/story/kovdorskiy_gornoobogatitelnyiy_kombinat_5668458

[4] Vasiliev M V 1975 Combined Transport in Open-Pit Mines (Nedra: Moscow) p 308

[5] Vasiliev M V and Yakovlev V L 1972 Scientific Foundations of Designing Open-Pit Transport (Nauka: Moscow) p 202

[6] Vasiliev M V 1973 Selection of Open-Pit Transport Type (Nedra: Moscow) p 192

[7] Vasiliev M V and Yakovlev V L 1984 Cyclical-and-Continuous Technology and its Development Experience in Design, Construction and Operation of Cyclical-and-Continuous Technology Complexes in Open Mining (All-Union Sc.-Techn. Seminar Theses, Gubkin) pp 9–12

[8] Simkin B A, Dikhtyar A A, Ziborov A P, Chaplygin N N, Kamenshchuk V P and Shuboderov V I 1985 Complex Mechanization of Cyclical-and-Continuous Technology Processes in Open-Pit Mines (Nedra: Moscow) p 195

[9] Tartakovsky B N et al 1978 Cyclical-and-Continuous Ore Mining Technology at Open-Pit Mines of Krivbass (Tehnika: Kiev) p 178

[10] Tartakovsky B N, Drukovany M F, Polyakov N S et al. 1973 Development and Introduction of Cyclical-and-Continuous Mining Technology at the Novokvirivozhsky GOK Mining journal vol 4 pp 5–8

[11] Reshetnyak S P 1997 Creation of CCT Systems with In-Pit Mobile Crushing-and-Conveying Complexes Doctoral Dissertation in Technics (Apatity: Institute of mining of Kola Science Centre of RAS) p 422

[12] Reshetnyak S P 2015 Perspectives of Cyclical-and-Continuous Technology at Open-Pit Mines Mining Machinery pp 52–59

[13] Karmaev G D 1978 Research of Efficiency and Application Areas of Various Types of Conveyors at Open-Cast Mines Candidate's Dissertation in Technics (Sverdlovsk: Institute of mining of USSR's Ministry of Iron and Steel Industry) p 188

[14] Karmaev G D and Glebov A V 2012 Selection of Mining Equipment for Cyclical-and-Continuous Technology for Open-Pit Mines (Ekaterinburg: Institute of mining of Ural Branch of RAS) p 296

[15] Shilin A N 1972 Investigation of Open Development of Rock and Ores Using Conveyor Transport Doctoral Dissertation in Technics (Sverdlovsk: Institute of mining of USSR's Ministry of Iron and Steel Industry) p 359

[16] Malgin O N, Sytenkov V N and Shemetev P A 2004 Cyclical-and-Continuous Technology at Deep Open-Pit Mines (Tashkent: Fan) p 337
[17] Yakovlev V L 2013 Perspective Solutions in Field of Cyclical-and-Continuous Technology of Deep Open-Pit Mines *Mining journal* vol 4–5 pp 51–56

[18] Yakovlev V L, Karmaev G D, Bersenev V A and Sumina I G 2015 About Moment of Introduction of Cyclical-and-Continuous Technology at Open-Pit Mines *Proceeding of University. Mining journal* vol 3 pp 4–11

[19] Glebov A V, Bersenev V A, Karmaev G D, Semenkin A V 2017 New Approaches and Solutions for Application of Cyclical-and-Continuous Technology at Open-Pit Mines *Mining journal* vol 6 pp 49–52

[20] Kuleshov A A 1980 *Powerful Excavator-and-Vehicle Complexes of Open-Pit Mines* (Moscow: Nedra) p 317