Enhancement of stripping operations in the development of the Chernogorskoe coal deposit

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Abstract. The article presents the rationale for the process flow design of transportless stripping, which allows increasing the efficiency of overburden operations in the combined development system of the Chernogorsky field, based on the established dependencies of changes in the main technological indicators on the height of the dragline placement.

1. Introduction
The program for the development of the coal industry in Russia for the period up to 2030 determines the need to increase the competitiveness of coal-mining enterprises. According to the Federal State Budgetary Institution “CDUTEK” and Rosstat, over the period of 2006–2017, open coal mining output in Russia grew by 51% [1-3]. At the same time, the rate of growth in the volume of overburden operations is ahead of mining by three times, and over the same period, overburden volumes increased by 152% (Fig. 1). Under current conditions, the intensification of overburden operations is an urgent scientific and practical task and is an effective way to increase the competitiveness of a coal-mining enterprise [4-8].
2. Materials and methods

The Chernogorskoe coal deposit is represented by a suite of steep, complex structural seams. The development of the field is carried out according to a combined system – transportless mining with the use of dragline excavators and transportation with dump trucks.

Increasing the depth of mining at the Chernogorskoye field inevitably leads to an increase in external overburden [9-14]. On the “Stepnoy” horizontal section for the period of 2007–2017 stripping ratio growth was 24% while stripping volumes increased by 74%, production by 41% [15-17].

When mining the horizontal section, a complicated process flow design of a transport-free overburden is applied, with re-excavation and dumping of a two-level dump (Fig. 2a). Analysis of the production of overburden operations and the design flow chart showed that the possible production capacity of the mine is 3,500 thousand tons with this material transfer process flow. Figure 3 shows a graph of production for the period 2007-2017. Since 2012, production volumes exceeded 3.5 million tons and by 2017 amounted to 4.2 million tons.
Figure 2. Process flow design of stripping operations
a - project diagram, b - proposed scheme, c - scheme for determining the dependence of the main technological parameters on the height of the dragline placement

Figure 3. Production volumes 2007-2017.
The graph in Fig. 4 reflects the dynamics of stripping work by type for the same period. Since 2012, there has been a significant increase in the volume of transport stripping associated with an increase in the depth of mining reserves and an increase in production volumes. The volumes of non-transport stripping have been declining since 2012, in turn, the re-excavation volumes have been growing since 2014 when the production volume reached 4 million tons, the re-excavation volumes exceeded the volumes of stripping operations performed by draglines.

Figure 4. Stripping work by type in 2007-2017

In the existing mining engineering and mining-geological conditions, with a low thickness of developed coal seams and relatively low height of developed overburden benches, growth of productivity of equipment complexes, the speed of movement of bottom faces along with the work front increases. The limiting stage in the technological chain is the transportless stripping (including re-excavation). As a result, there is a lag in the speed of movement of the faces, developed using the best transport technology, as well as the speed of moving the faces of the re-excavation. These factors contribute to the redistribution of the structure of re-excavation in the direction of the growth of the volume of transport re-excavation and a decrease in the volume of transportless one [18]. It is also difficult to maintain the necessary technical standard of ready-for-excavation stocks.

Based on the developed process flow design of transportless stripping [19, 20] (Fig. 2b), the dependencies of the main technological parameters on the height of the dragline placement (Fig. 2c) were identified. With an excavator placement height of 18 m from the roof of the “Velikan” 1 stratum, the re-excavation coefficient decreases by 19.7% from 0.317 m$^3$/m$^3$ to 0.255 m$^3$/m$^3$, which will make it possible to increase productivity by 6.3% due to redistribution of volumes [9]. After redistribution of volumes, the re-excavation coefficient will be 0.240 m$^3$/m$^3$ (Fig. 5). The use of the developed space to accommodate the dumps at the maximum with a given height of dragline placement.
Figure 5. The dependence of the coefficient of re-excavation ($K_{re-ex}$) and the capacity of the internal dump ($V_{dump}$) from the height of the dragline placement.

The turnover of overburden is minimal, and the rate of stock preparation is maximum (Fig. 6). The speed of moving the faces in case of transportless stripping increases by 17.3% when the dragline is operating on the overburden bench of “Velikan” strata and up 71.1% when two draglines are working on the lower horizons (Fig. 7).

Figure 6. Dependence of stock preparation speed ($V_{prep}$) and overburden turnover ($P_{over}$) on the height of the dragline placement.
Figure 7. Chart comparing the speed of faces moving in case of transport-free stripping.

In terms of the combination of transport and transportless systems existing in the mine, the standard for ready-to-excavate reserves is assumed to be 15 daily coal output for the planned period and will be 175 thousand tons, with a monthly production plan of 350 thousand tons.

Due to the peculiarities of the existing process flow designs, the coal reserves prepared for excavation are not standardized.

Using the proposed flow chart, it is possible to prepare the required amount of reserves for the “Velikan” 1 stratum. The difference in the rate of preparation of reserves, which is 29.5 thousand tons/month (Fig. 8), will allow achieving the required standard of reserves in six months.

Figure 8. Cumulative reserves preparation schedule.

3. Conclusion
Analysis of the dependence of the main technological parameters on the height of the dragline placement using the proposed variant of the process flow design made it possible to determine the optimum height of the dragline placement within 8 ÷ 18 meters from the roof of the “Velikan” stratum. The re-excavation factor is reduced by 19.7%, which will increase the productivity of the transportless stripping by 6.3% due to the redistribution of volumes.

Maintaining the standard of reserves ready for excavation should ensure uniform operation of the mine in terms of coal production and quality. The uniformity of the enterprise will allow more efficient use of excavating, loading and mining transport equipment. The increase in equipment productivity leads to a decrease in the value of fixed assets by reducing the total amount of equipment used. These factors contribute to the intensification of stripping operations.
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