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# PRODUCTION ACTIVITY ANALYSIS METHODOLOGY FOR OPEN PIT COAL MINES (IN TERMS OF SHESTAKI OPEN PIT MINE)

*Russian coal industry possesses every opportunity to become the modern and highly competitive sector of economy. The competitive advantages of Russian coal companies within the domestic energy economy include, among other things: huge coal reserves sufficient for 600 years at the current level of production; appreciable experience of utilization of this energy resources for sustainable power supply, especially under crunch; possibility to enter the world market; considerable potential to enhance efficiency; diversity of coal products; adaptability to fluctuating market; fusion with the priority trends in the innovative economical development; contribution to the regional energy security.*

*Russia is one of the leading coal producers in the world. Russia holds one third of the global coal resources and one fifth of the known resererves — 193.3 bln t. Given the current level of coal mining, these reserves are enough for more than 550 years.*

*In 2016 Russian coal companies produced 385.7 Mt of coal (increment by 3% as compared with 2015). The dominant share in the production belongs to open pit mining — 72.9%. Open pit coal mines produced 281.1 Mt of coal in 2016 (increment by 4% as against 2015).*

*This article describes the procedure for the analysis of performance of open pit coal mines in Russia. The procedure has been trialed in terms of open pit mines with the medium annual production output (between 1 and 5 Mt). It is found that out of such mines, the most sustained rate of increase in overall production and in the economic performance is a feature of companies that produce coal of the most valuable ranks. In terms of a typical representative of such companies — Shestaki open pit coal mine, the authors have developed the performance forecast algorithm for the nearest 1–2 years. It is recommended to use the algorithm to analyze low (to 1 Mt) and high (above 5 Mt) open pit performance.*

***Key words:*** *coal, coal production, open pit mine, production output, cost, sales price*
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## Introduction

Russian coal industry possesses all capabilities to become an advanced branch of economy with the high-quality products. Russian coal mining companies have many competitive advantages in the framework of the domestic fuel-and-power sector: tremendous coal reserves; large experience in utilization of this type of energy resources, especially in crisis situations; opportunity to come into the world market; high potential to enhance efficiency; diversity of coal products; adaptability to varying market environment; tight integration into priority lines of innovative economic development; essential contribution to the regional energy security.

Russia is one of the world leaders in coal production. The Earth's interior inside Russia holds one-third of global coal reserves and one-fifth of the known reserves — 193.3 bln t [1]. Given the current level of coal production, these reserves are enough for more than 550 years [2].

Coal mines both in Russia and in other countries face with the common problems connected with the environment protection, occupational safety of miners, improvement of coal product quality by means of deeper conversion, and enhancement of economic efficiency of coal mining [2–13]. These problems are of different acuteness and urgency per specific mines, but in principle can be grouped with respect to a mining method, volume of production and a location area.

## Analysis of trends in open pit coal mining

In 2016 Russia produced 385.7 Mt of coal. The prevailing percentage belongs to the open pit mining method — 72.9%. In 2016 open pit mines produced 281.1 Mt of coal (increment by 4% as against 2015).

With respect to coal production output (in 2016), it is suggested to divide all open pit mines in Russia into three groups: small (output to 1000 thou t); medium (from 1000 to 5000 thou t) and large (output above 5000 thou t). Group I is the most numerous — 63 open pits (51% of the total number); then goes group II — 46 open pit mines (38%) and group III ends the list — 14 open pit mines (11%).

This article analyzes performances of group II open pit mines in 2006–2016. The average annual coal output in these open pit mines changed between 1891.7 and 2471.4 thou t in the mentioned period of time and grew by 19% during 10 years. On the average, coal production output increased by 18.33 thou t annually.

Aiming to analyze factors that influence the increase in the coal production output, we choose a subgroup of open pit mines with the progressive rate of the production output growth for the last 10 years in Group II (see the **Table**).

The open pit mines in this subgroup show the most pronounced tendency of incremental coal production. As for the other open pit mines in group II, their production capacity for 10 years remained nearly the same.

Searching the cause of such anomaly, it is found that in the subgroup with the stable increment in production, the lion's share belongs to bituminous coal (85%) and lignite only makes 15%. The weighted average price of coal in this subgroup is twice as much as the coal price at the other open pit

**Performance of open pit mines with the sustained rate of increment in coal production output**

| Open pit mine | Production output in 2016, thou t | Increment rate, % | Average annual cost of 1 t of coal, Rub | Rank of coal |
|---|---|---|---|---|
| Kaltansky | 3989.12 | 2.0 | 1210,6 | Lean |
| Permyakovsky | 1731.99 | 13.9 | 904,82 | Jet |
| Kiselevsky | 2554.82 | 4.0 | 2316,48 | Jet, oxidized |
| Berezovsky | 3382.63 | 6.4 | 2458,53 | Low-caking |
| Kharanorsky | 2889.2 | 3.5 | 656,47 | Coking, lean-caking, oxidized |
| Vostochno-Beisky | 3233.5 | 13.6 | 1820,42 | Coking-caking, lean |
| Azeisky | 2215.9 | 18.1 | 662,34 | Lean-caking, lean |
| Luchegorsky | 3837.8 | 25.4 | 1066,11 | Lignite 1 |
| Zadubrovsky | 1107.28 | 73.7 | 784,28 | Jet |
| Shestaki | 1276.00 | 5.2 | 2144,6 | Coking, coking-caking, coking-lean, low-caking, gas-fat oxidized |
| Korkinskie | 1334.35 | 10.6 | 805,9 | Lignite 3 |
| Vostochny | 4230.19 | 13.0 | 2157 | Jet-gas |
| Vostochnoe Mine Management | 1855.37 | 5.7 | 1712,33 | Jet |
| Total | 33638.0 | | | |

mines in group II. The latter also have higher share of lignite production, which is 35%. Owing to this, such open pit mines show a general trend of reduction in the production output. Demand for lignite lowers, which affects performance of such mines.

Below in the text, dynamics of the performance of the medium-capacity mines is examined in terms of Shestaki open pit mine.

Shestaki open pit mine of Stroiservis ZAO is located in the Gurievsk district of the Kemerovo Region and develops Bachaty bituminous coal field. Shestaki produces high-grade power-generating and coking coal that enjoys high demand in Russia and abroad. Shestaki open pit mine also exports coal.

Performance of the open pit mine is analyzed based on a set of indexes (**Fig. 1**).

It is seen in Fig. 1 that coal production slightly dropped in 2007. In 2008 the production output recovered. No considerable changes took place in the recession year of 2009. Since 2013 the open pit gradually increases coal output.

In 2008 coal cost appreciably grew (by 48%) as compared with the previous years but decreased in 2009. The cost remained unaltered and sufficiently high between 2010 and 2013 but suffered a sharp fall, the heaviest for the last 10 years, in 2014. Such dynamics implies that the cost was reduced in the period of recession with the aim of expenses saving but the reduction cannot be long-term as the production to be continued requires stripping, otherwise it stops, thus the cost grows later on.

The average sales price of coal reached maximum in 2012. It grew sharply in 2010 and experienced slight fluctuations in recent years.

The open pit mine under study operates 14 mining shovels, models EKG-5A and EKG-

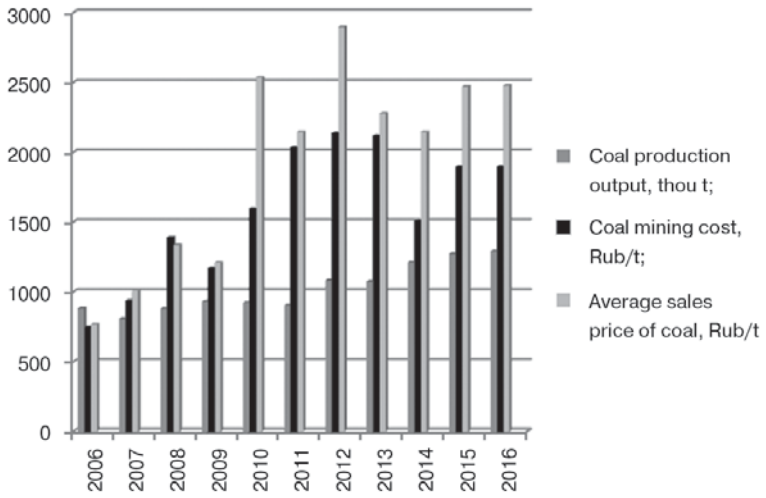


**Fig. 1. Shestaki open pit mine performance dynamics**

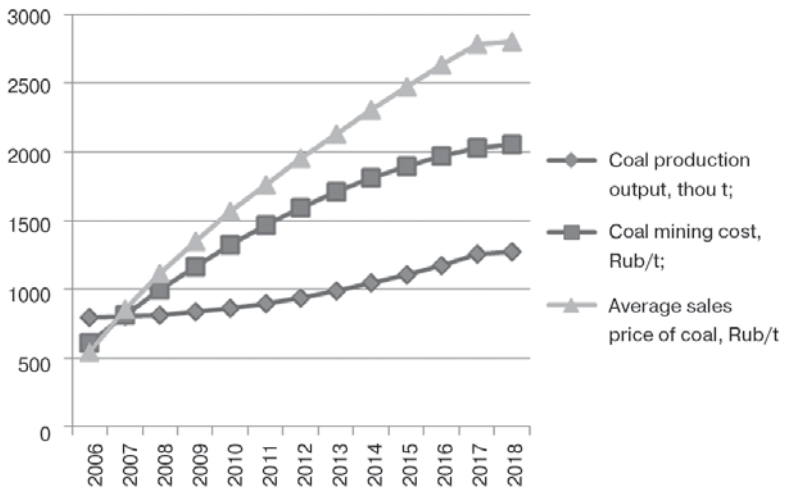


**Fig. 2. Trends of production activities of Shestaki open pit mine**

5U of the domestic manufacture. From the analyses of the arrangement and use, the number of the shovels is excessive for the coal production of 1276 thou t. The shovels are of obsolete models, and it is necessary to renew the mining equipment fleet and to employ more efficient machines.

In terms of Shestaki open pit mine, the trends in production activities of coal mines with the positive performance dynamics are studied and the performance forecasting for 2017–2018 is made using the equations of regression of the time series with plotting the trend lines (**Fig. 2**).

The plots of the trend lines clearly show the incremental production of coal at the high confidence factor ($R^2$=0.89). The forecasted cost of 1 t of coal for 2018 is 2057.8 Rub, i.e. a mild increase is expected at $R^2$ = 0.735. The average sales price of coal in 2018 will reach 2803.2 Rub/t. Thus, it is possible to draw a conclusion that the performance of the discussed open pit mine will have positive dynamics in the next 3–4 years given the preserved terms and conditions of development.

## Conclusion

The research findings allow coming to the conclusions that:

Open pit coal mines can be grouped based on the coal production output into small (group I — 51%), medium (group II — 38%) and large (group III — 11%);

Open pit mines in group II, with the positive dynamics of the performance, mainly produce bituminous coal; the weighted average price of coal in these open pits is two times higher than in the other open pit mines inside this group;

For group II open pit mines producing lignite, there is a trend toward the reduction in the production output: demand for lignite decreases, which affects the performance of these open pit mines;

The algorithm developed to analyze performance of coal mines and tested in terms of Shestaki open pit mine allows sufficiently reliable prediction of the performance for 1–2 years;

For the objective estimation of production activities at all open pit coal mines in Russia, it is necessary to implement the proposed algorithm in terms of open pit mines from groups I and III.

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