

# Coal Mining Machinery Development As An Ecological Factor Of Progressive Technologies Implementation

A B Efremenkov<sup>1,a</sup>, A A Khoreshok<sup>2,b</sup>, S A Zhironkin<sup>3,c</sup>, A V Myaskov<sup>4,d</sup>

<sup>1</sup> Yurga Technological Institute (Branch) of National Research Tomsk Polytechnic University

Leningradskaya st. 26, Yurga, Russian Federation, 652055

<sup>2</sup> T.F. Gorbachev Kuzbass State Technical University

Vesennyyaya st. 28, Kemerovo, Russian Federation, 650000

<sup>3</sup> National Research Tomsk Polytechnic University

Lenina av. 30, Tomsk, Russian Federation, 634050

<sup>4</sup> National University of Science and Technology MISiS, College of Mining

Leninsky av. 4, Moscow, Russian Federation, 119049

E-mail: ytitpu@tpu.ru<sup>a</sup>, haa.omit@kuzstu.ru<sup>b</sup>, zhironkin@inbox.ru<sup>c</sup>, mgi@misis.ru<sup>d</sup>

**Abstract.** At present, a significant amount of energy spent for the work of mining machines and coal mining equipment on coal mines and open pits goes to the coal grinding in the process of its extraction in mining faces. Meanwhile, the increase of small fractions in mined coal does not only reduce the profitability of its production, but also causes a further negative impact on the environment and degrades labor conditions for miners. The countermeasure to the specified processes is possible with the help of coal mining equipment development. However, against the background of the technological decrease of coal mine equipment applied in Russia the negative impact on the environment is getting reinforced.

## 1. Introduction

For the last decade the intensive development of mechanic methods of coal mining has led to a significant deterioration of the coal quality. According to statistics even in 1975 the mechanization level (for coal seams with the dip angle up to 35 degrees) in major coal regions of Russia was 73.7-90.0%. Now its indicator has reached 100% [1-2].

Currently, the main part of the underground coal mining is carried out by narrowly gripping coal-mining machines [3-5].

With the growth of their power capacity there is a tendency to increase the degradation of extracted coal. Over-degraded mined coal badly affects the economic performance of the mines. Most of coal mining enterprises losses are associated with constantly deteriorating quality of the coal.

Increased varietal composition requirements are mainly implemented to energy coal. Excessive degradation in size of such coal complicates their separation on classes, transportation and leads to a significant decline of coal selling prices.



Significant part of the extracted coal, and in Kuzbass region (Western Siberia, Russia) it reaches up to 60%, comes to the coking [6]. All of coking coal is subjected to upgrading operations. Costs of small classes of coal upgrading by washing methods are in 4-8 times higher than for large classes.

## 2. Material and Method

In recent years, the quality of coal products is associated with an increase of the ash content of mined coal, and less attention is paid to its varietal composition. But these factors are interconnected with each other. So, with the increase in volumes of coal upgrading, the growth of crushed coal leads to the output of much larger number of un-upgradable wastage. Its processing and inclusion in the material production require additional costs.

Thus, from an economic point of view, the advisability of reducing the degradation in size of extracted coal is undeniable.

Coal over-degradation in size in mechanized extraction also leads to significant dust emissions. In this specific dust emission exceeds the permissible limits (MPC). High air dust content in coal mine complicates the work of the staff, increases the risk of work operations and reduces productivity. Therefore there is a need to stop coal-mining machine, to apply additional measures of dust suppression which complicate the organization of the working process, reduce productivity of mining faces.

In the structure of occupational diseases of miners the leading place is taken by dust pathology of the respiratory system. Especially dangerous for miner's health is the dust of coking coal.

High saturation of Kuzbass with coal companies, chemical plants, power stations significantly degrades the environment. Rapid development of new mines and open pits is encouraged by the growth of mining machinery specific productivity. That increases not only the risk of the air pollution but the water contamination [7-8].

Currently, total emissions into the air of Kuzbass region from stationary sources are on average 1.5 million tons for the year, including 0.18 million tons from coal enterprises (11.7%). Coal industry enterprises emit up to 9.3 thousand tons of suspended solid contaminants annually polluting residential areas of Kuzbass miners' towns [9-10]. The given social and environmental aspects of the coal degradation in size problem show urgent necessity to reduce mined coal crushing.

Deterioration of technical and economic parameters of coal enterprises, including the quality of extracted coal has been caused by poor supplying the industry with modern equipment, materials and by the narrow use of modern coal mining technologies, by increasing trend of immunity of coal production of the science and technology achievements, by the complexity of geological conditions of coal mining.

The enterprises of coal industry operate 30-35% of physically deteriorated and depreciated equipment, and only 10-15% of used mining equipment complies with modern technical level widely accepted in the world [11]. In addition, the most of used mining equipment is operated in inappropriate geological and technical conditions.

We also observe clearly insufficient efforts of domestic researchers involved in the development of new coal mining equipment and improvement of existing machinery.

From 1963 to 1993, Russian coal industry produced about 80 new and modified pieces of coal mining machinery [11].

For their comparison using the quality criterion (the factor of grade) the perfection coefficient  $k$  and the fineness index  $km$  were calculated. These indicators uniquely characterize the cutting modes from the grinding point of view. Obtained index  $km = 0.015-0.02$  corresponds to the effective cutting tools and methods and progressive cutting regimes.

So, today the situation at coal industry enterprises shows that the latest machinery science achievements cannot find a proper application.

Thus, for example, to equip narrowly gripping coal-mining machines, which carry out the bulk of the underground coal mining, we developed screw actuators with different types of cutters and disc cutters.

They provide a large increase in the output of large coal grades by 6-14%. Area of application of the screws with such cutters is only 20-25% of developing coal seams and screws with disc cutters do not even come out of the prototype stage, although there are some technical specifications for these screws and disc cutters. The reason for the limited use of these screws is that the extra cost of using more expensive and less reliable cutters screws is referred to the segments of coal mines, and the economic effect is achieved by the whole mine only after coal sorting and upgrading.

Thus, the actual coal miners (segment, mine) are not economically stimulated by improving the quality of the extracted coal and consequently, by implementing new technology. In addition, shortcomings in the existing coal pricing in Russia today give a small difference in the price for concentrate and raw coal, which results in a small economic effect of improving coal varietal composition.

### 3. Results and Discussion

To ensure the improvement of the coal grade in the whole industry it is required to plan and standardize the varietal composition of the coal produced at all stages of the mining process. For operational analysis the varietal composition techniques it is necessary to assess the contribution of each operation of mining process in the coal crushing and, above all, the contribution of destruction as the basic operation.

For this purpose, in recent 15 years sufficient work of researches around the world has been done to improve the working bodies of coal-mining and tunneling machinery [12-19].

Analysis of the researches in this area shows that the special attention should be paid to the following directions:

- the study and improvement of coal transportation and loading process by screws and other working bodies;
- selecting the optimal parameters of cutting diagrams and arrangement of cutting tools application area;
- the study of coal crushing and improving the efficiency of coal-mining machines according to the factor of mined coal's grade;
- the study of regime and parameters of destruction;
- improving the reliability and durability of coal-mining machine working bodies and determining the rational area of their application.

Thus a large amount of theoretical and experimental studies conducted in the last decade and aimed at improving the working bodies of the narrowly gripping coal-mining machines, revealed qualitative and quantitative dependences between the loading capacity of the screws and their constructive and regime parameters. Based on these we developed a number of recommendations for their improvement.

The research in the field of rational choice of cutting schemes and cutters' placement were carried out in the following aspects: obtaining better-quality coal composition and the least dust emission, effective work in seams with rock layers and inclusions, and reducing the dynamic loads on the drive.

The methodology of choice of rational cutting schemes and cutters' placement on the screw comprised the basic regularities of coal cutting process by a single instrument. The main conclusion was that the specific energy consumption and output of degradation in size coal decrease hyperbolically with the increase in average cutting depth values  $h_{cp}$  and cross-section of the chips  $Scp$ . The choice of rational values of  $h_{cp}$  and  $Scp$  is recommended to make in the area of stabilization of specific energy consumption and grade.

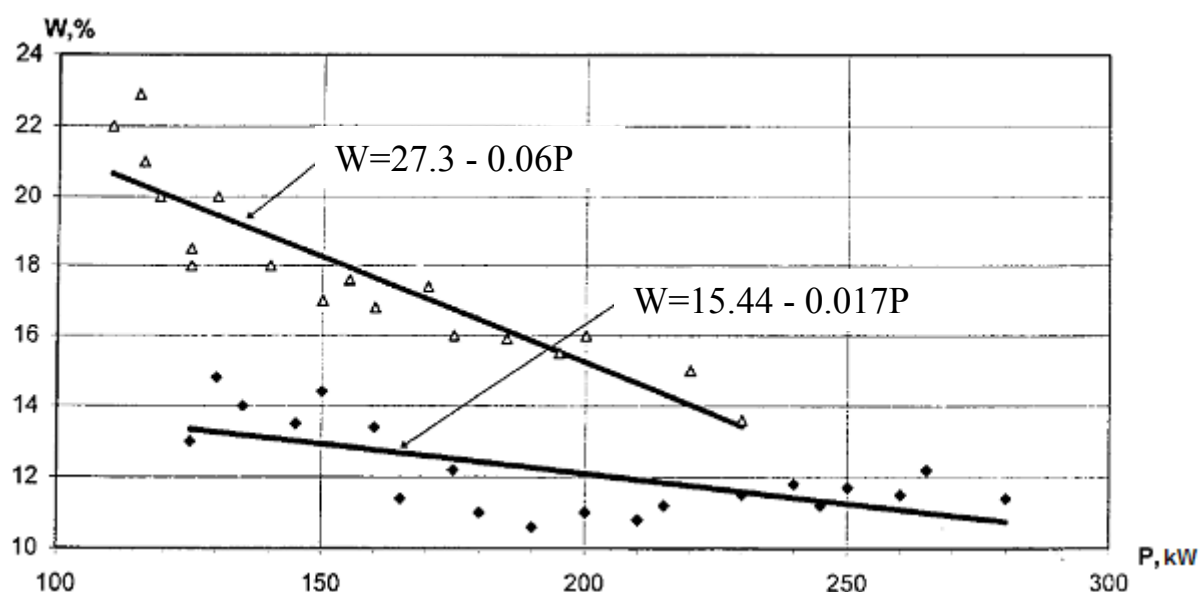
The sufficient amount of researches is devoted to the problems of coal grinding and increase in the output of high-quality coal [20-24].

It should be noted that the studies of coal grinding and a choice of rational parameters of destruction and schemes of tools are closely connected and, as a rule, were carried out comprehensively. However, considering the great economic importance in energy, social and economic aspects, we will focus on this issue, as it's no doubt that the growth of mechanized coal extraction and power capacity of coal-mining machine lead to a decrease in the output of high-quality coal.

The physical nature of the coal grinding and brittle rock by cutting tools can be explained by the mechanism of destruction by cutters. It determines the presence of the continuous series of coal pieces of various sizes, ranging from fine (dust) fractions in the products of coal destruction.

The main factors determining varietal composition of coal are the following: coal destructibility, destruction scheme parameters and cutting conditions, the methods of mining face processing, working body design.

With the increase the share of narrowly gripping coal-mining machines in the volume of coal production and their growing power available in Kuzbass and other coal basins we observe the tendency to increase the volumes of degraded in size mined coal (Fig. 1).



**Figure 1** – The dependence between output of the coal of large and middle fractions ( $W$ , %) and coal-mining machines' power capacity ( $P$ , kW):  $\Delta$  - for coal company "Kuzbass Coal Inc.";  $\blacktriangle$  - for the whole Kuzbass

Fig. 1 shows the variation of the dependence between the output and large-medium grades coal and power capacity of coal-mining machinery.

Analysis of these dependences shows a systematic decrease in the output of large and middle classes coal, an increase in the output of coal fines, and the relationship of these indicators with power capacity of coal-mining machines. Naturally, overgrinding of mined coal cannot positively affect the economic indicators of coal mines.

It is known that high requirements regarding varietal composition of coal are presented mainly to energy coals.

Their excessive grinding together with the increasing complexity of dividing the coal into classes (sorting) and transportation, is accompanied by a significant decline in selling prices. For example, a change in the actual wholesale price of energy coal, taking into account its quality, reaches up to 180%, i.e. selling price of coal, depending on its sort, changes in 1.5-3 times.

The main part of coal (about 60%) produced in Kuzbass comes to coking.

In recent years the amount of coal production in Kuzbass having been constantly increasing but the share of coal upgrading is declining, against the raise of output of small and middle coal fractions.

Crushing ability for coal from various seams is quite different.

Therefore, even using the same type of coal-mining machines with established modes of operation can lead to varietal composition of mined coal. It was proved by the sieve analyses of samples taken

on “Leninskugol Inc.” enterprise directly in the mining faces of a number of mines. The culm output (0-6 mm grade) was from 32 to 60% and the output of coal with class less than 13 mm did not exceed 40-50%.

#### 4. Conclusion

The foregoing leads to the conclusion that the reduction in degradation in size of mined coal is of great economic importance for the coal industry, not only in Russia but also in other coal producing countries.

Coal overgrinding during cutting does not only reduce its commercial value, but also provides a significant dust generation, which is the starting point of high dust emissions of operating coal-mining machines in working faces.

The high dust content complicates the work of the staff, increases occurrence rate of industrial injuries and reduces productivity of mining faces. For example, in mechanized faces with the largest dust emissions it is almost impossible to perform working operations on the outgoing air stream.

The analyzed data testify that the work of modern coal-mining machines in a significant number of mining faces is characterized by a low grade of produced coal and very large dust emission. It has a great importance for environment-friendly use of natural resources, which will be the key point of interest in coming years [25].

#### 5. Acknowledgement

The research was made in T.F. Gorbachev Kuzbass State Technical University under State Assignment N10.782.2014 K “Development of high-performance process for complex processing of low-grade coals and waste coal with producing a low ash coal-and-oil concentrate, composite fuels, rare earth and trace elements”.

#### References

- [1] Khoreshok A A, Zhironkin S A and Tyulenev M A et al. 2016 Innovative technics of managing engineers' global competencies IOP Conference Series: Materials Science and Engineering 142 (1) 012122
- [2] Tyulenev M A, Lesin Yu, Vik S and Zhironkin S 2016 Methodological Bases of Advanced Geo-ecological Problems Resolving in Neo-industrial Clusters Proceedings of the 8th Russian-Chinese Symposium “Coal in the 21st Century” pp 333-336
- [3] Ryzhkov YA, Gogolin VA and Karpenko NV 1992 Modelling the structure of solid masses of lump and granular materials (plane problem). Journal of Mining Science 28(1) pp 6-12
- [4] Khoreshok A A, Buyankin P V, Vorobiev A V, Dronov A A 2016 Simulation of Stress-Strain State of Shovel Rotary Support Kingpin IOP Conference Series: Materials Science and Engineering 127 012014
- [5] Ryzhkov YA, Lesin YV, Gogolin VA, Karpenko NV 1996 Modeling the structure of fragmented and granular material: Three-dimensional problem. Journal of Mining Science 32(3) pp 188-191
- [6] Tyulenev M, Zhironkin S, Kolotov K and Garina E 2016 Background of innovative platform for substitution of quarry water purifying technology Pollution Research 35 (2) pp 221-226
- [7] Tyulenev M A, Gvozdkova T N and Zhironkin S A et al. 2016 Justification of Open Pit Mining Technology for Flat Coal Strata Processing in Relation to the Stratigraphic Positioning Rate Geotechnical and Geological Engineering 34 (6) doi:10.1007/s10706-016-0098-3
- [8] Tyulenev M A and Lesin Y V 2014 Justification complex purification technology open-pit mines wastewater Symposium of the Taishan academic forum – Project on mine disaster prevention and control pp 441-444
- [9] Tyulenev M, Zhironkin S and Litvin O 2015 The low-cost technology of quarry water purifying using the artificial filters of overburden rock Pollution Research 34 (4) pp 825-830
- [10] Lesin Y V, Luk'yanova S Y and Tyulenev MA 2015 Formation of the composition and proper-

- ties of dumps on the open-pit mines of Kuzbass IOP Conference Series: Materials Science and Engineering 91 (1) 012093
- [11] Tyulenev M A, Zhironkin S A, Garina E A 2016 The method of coal losses reducing at mining by shovels International Journal of Mining and Mineral Engineering 7 (4) DOI: 10.1504/IJMME.2016.10000781
- [12] Andreev G E 1991 A review of the Brazilian test for rock tensile strength determination. Part I: calculation formula Mining Science and Technology 12 pp 445-456
- [13] Peide S 1991 Geothermal prediction of country rock in deep mines Mining Science and Technology 10 pp 433-438
- [14] Shixiong Zhang and Guangxu Tong 1991 Influence of block boundary weakening on the caving process Mining Science and Technology 10 pp 157-166
- [15] Yuejin Li and Singh R N 1991 An overview of condition monitoring and an expert system for longwall mining machinery Mining Science and Technology 12 pp 279-290
- [16] Nazarova L A, Freidin A M and Neverov A A 2005 Chamber Mining with Roof Caving at the Nikolaevsk Mine Journal of Mining Science 41(4) pp 342-349
- [17] Neverov S A 2012 Types of the Orebodies on the Basis of the Occurrence Depth and the Stress State. Part II: Orebody Tectonotypes and Geomedium Models Journal of Mining Science 48(3) pp 421-428
- [18] Neverov S A and Neverov A A 2013 Geomechanical Assessment of Ore Drawpoint Stability in Mining with Caving Journal of Mining Science 49 (2) pp 265-272
- [19] Zhurilo A G, Zhurilo D Yu and Rudnev A V 2015 Brief review of the development of cutting tools Ferrous metals 1 pp78-86
- [20] Tanaino A S and Botvinnik A A 1999 Three-dimensional solution of mining-geometric problems in a graphic dialog regime in planning opencasts Journal of Mining Science 35 (6) pp 640-653
- [21] Cushtar C, Matti M and Veron S. 2011 Industrial coal demand in China: a provincial analysis J. Resource and Energy Economics 33 (1) pp12-35
- [22] Demirel N 2011 Effects of the rock mass parameters on the dragline excavation performance Journal of Mining Science 47 (4) pp 441-449
- [23] Oparin V N, Cheskidov V I, Bobyl'sky A S and Reznik A V 2012 The sound subsoil management in surface coal mining in terms of the Kansk-Achinsk coal basin Journal of Mining Science 48 (3) pp 585-594
- [24] Mattis A R, Cheskidov V I. and Llabutin V N 2012 Choice of the hard rock surface mining machinery in Russia Journal of Mining Science 48 (2) pp 329-338
- [25] Sherer D and Attig T 1983 Ethics and the Environment (New Jersey: Prentice-Hall, Inc.) 554 p