THEME
CHINESE COAL
IN THE XXI CENTURY:
MINING, GREEN
AND SAFETY

MINING 2014

泰山学术论坛
Taishan Academic Forum

TAISHAN
ACADEMIC
FORUM

PROJECT
ON MINE
DISASTER
PREVENTION
AND
CONTROL

OCTOBER 17/20, 2014
QINGDAO, CHINA

EDITED BY
WEIJIA GUO, YUNLIANG TAN,
YONGJIE YANG, SHASHA YAN,
DONGMEI HUANG – CHINA

ATLANTIS
PRESS

泰山学术论坛
Taishan Academic Forum

MINING 2014

Taishan Academic Forum – Project on Mine Disaster Prevention and Control

October 17–20, 2014
Qingdao, China

***Theme*: Chinese Coal in the XXI Century: Mining, Green and Safety**

Edited by:

Weijia Guo, China
Yunliang Tan, China
Yongjie Yang, China
Shasha Yan, China
Dongmei Huang, China

ATLANTIS PRESS

ATLANTIS PRESS
AMSTERDAM – PARIS – BEIJING

Advances in Engineering Research
(ISSN 2352-5401)

The proceedings series *Advances in Engineering Research* (ACSR) aims at publishing proceedings from conferences on the theories and methods in fields of engineering applied to multiple areas, including:

- aerospace engineering
- biological engineering
- civil engineering
- chemical engineering
- electrical engineering
- financial engineering
- industrial engineering
- material engineering
- mechanical engineering
- nanotechnology
- petroleum engineering
- textile engineering

www.atlantis-press.com

ISBN: 978-94-62520-28-8

This book is published by Atlantis Press, scientific publishing, Paris, France.

Taishan Academic Forum – Project on Mine Disaster Prevention and Control

October 17–20, 2014
Qingdao, China

***Theme*: Chinese Coal in the XXI Century: Mining, Green and Safety**

Hosted by:

- Education Department of Shandong Province, China
- Shandong University of Science and Technology, China
- Shandong Administration of Coal Industry, China

Edited by:

- Weijia Guo, China
- Yunliang Tan, China
- Yongjie Yang, China
- Shasha Yan, China
- Dongmei Huang, China

Sponsored by:

- Institute of mining and safety engineering, Shandong University of Science and Technology, China
- State Key Laboratory of mine disaster prevention and control, Shandong University of Science and Technology, China

Organizers:

- Education Department of Shandong Province
- Shandong University of Science and Technology, China
- Shandong Administration of Coal Industry, China

Co-organizers:

- Institute of mining and safety engineering, Shandong University of Science and Technology, China
- Control state key experimental cultivation base of mine disaster prevention, Shandong University of Science and Technology, China

Foreword

Mining technology is an important issue on resource exploitation, which is related to mine production security and energy supply. In order to promote the scientific and technological progress and international exchanges of the mining technology, the Taishan Academic Forum – Project on Mine Disaster Prevention and Control is to be held on Oct. 17-20, 2014, in Qingdao, China. The aim of the symposium is to summarize the modern coal industry achievements, in safety green mining methods and the related fields. There will be experts and scholars to attend the meeting, from the coal industry enterprises, universities, research institutions and other related fields of China and Russia.

The main topics of the symposium include: safety green mining methods, mine construction and modernization, the mining theories, methods and technology, the construction safety of mining and underground engineering, the operation and management of mining and underground engineering, etc.

The symposium is organized by the Education Department of Shandong Province, Shandong University of Science and Technology, Coal Industry Bureau of Shandong Province. It is undertaken by Institute of Mining and Safety Engineering, Shandong University of Science and Technology and State Key Laboratory of Mine Disaster Prevention and Control.

We are convinced that the symposium is going to play an important role in the development of the coal mining technology and international communication. Heartfelt thanks are extended to domestic and overseas scholars who have given great supports to this conference and all the authors who have presented the papers.

Weijia Guo, China
Yunliang Tan, China
Yongjie Yang, China
Shasha Yan, China
Dongmei Huang, China

Contents

Part I

Mine construction and modernization

Selection of A Rational Form for The Steel Winding Tower as A Preventive Measure to Increase Its Industrial Safety

KASSIKHINA Elena.G.,[1] PERSHIN Vladimir V.[1], BUTRIM Nikita O.[2], Qiao Weiguo[3]

1.Mining Institute, T.F. Gorbachev Kuzbass State Technical University, 650000 Kemerovo, Russia; 2.Department of Capital Construction and Investment Activities 'UK Michel Mining'125993 Moscow, Russia; 3.Shandong Science and Technology University, People's Republic of China

Abstract

Herein there is a new approach to improve industrial safety in terms of operation of the steel winding tower based on rational design solutions.

Keywords: Industrial safety, corrosion, defects, multi-functional steel jibs of winding towers-.

1. Introduction

In the complex of mine structures a winding tower takes a special place. Besides the fact that it is a high structure, designed to provide position of the pulleys of the hoist at a certain level, it is also a complex structure taking extremely loads from a hoist. It guarantees safe and reliable operation of the hoist for the entire period of its operation (35-45 years).

However, the results of a survey [1] showed that the actual operational life of the winding tower under high aggressive impact and without proper repair and maintenance is often reduced by a half versus to a standard service life.

2. Work description

According to the OJSC 'Kuzbassgiproshaht' and OJSC 'Sibgiproshaht' defining scope and range of loads for winding towers, which Kuzbass mines will need in the nearest future, the most popular are the winding towers for ventilation and auxiliary shafts of 7 ч 8m diameter with the marked center of the hoisting pulley +34,000 m ч +36,000m.

The available winding towers operating under similar conditions, as a rule, are four-pole and rig type (Fig. 1). The results of the expert appraisal [1] of their technical condition showed that most of the available structures have no access for rust removal and protective coating renewal. All these cause intensity of corrosion of the metal at rate of 0.8 ± 1 mm/year.

At the same time it was found out that a rig 1 (see Fig. 1) as the main supporting structure, transferring load from the hoist (including emergency) to the wellhead via the rig base of the winding tower, is the most exposed to the aggressive environment.

Typical defect of the rig parts is corrosion, and it mostly pronounced at the interface with the rig base. The most common damage of the rig base is a significant corrosion on the entire surface of its parts due to high humidity of the air entering from a shaft, corrosive gases and coal dust. The entire body of the rig under coating is also significantly exposed to corrosion due to the abundant condensation in winter time.

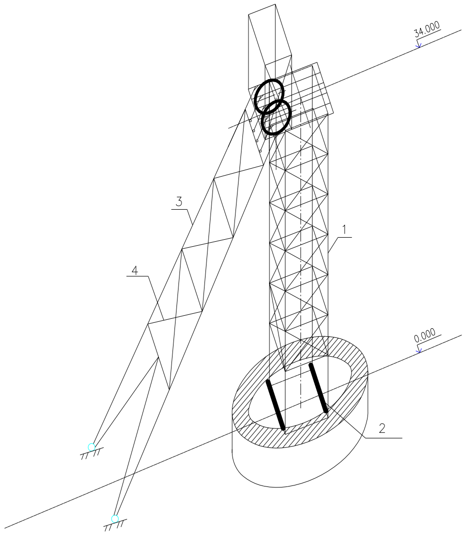


Fig. 1. Scheme of the steel single-cut four-post winding tower
1) rig; 2) rig base; 3) jib; 4) braces

Jib of the winding tower 3 provides stability of the structure, and takes effort from hoist, as well as a significant part of the emergency load. The main defects and damage of the jib can be attributed to deformation due to mechanical impact.

A large number of jibs promotes accumulation of coal dust, slag and lube in junctions of the jib and braces, and consequently, occurrence of significant corrosion in the stagnant areas.

The condition of stairs and fences does not affect the carrying capacity, but defects and damages of these parts affect the safety while winding tower repair and maintenance operations.

Traditional approaches to the design of winding towers, taking into account their failure-free operation and economic efficiency are crucial, by all means, at selection of rational constructive solutions.

However, solving the problem of provision of the longevity of structures and reduction of costs for their repair and maintenance is no less important for structures subjected to corrosive wear. Therefore, choosing cross sections and junctions of winding tower, an aspect of their resistance to corrosion as a guarantee of safety and durability must be considered.

The department ‘Construction of Underground Structures and Mines" KuzSTU has developed fundamental constructive solution of the steel winding tower (Fig. 2) [2] and made its prototype (Fig. 3).

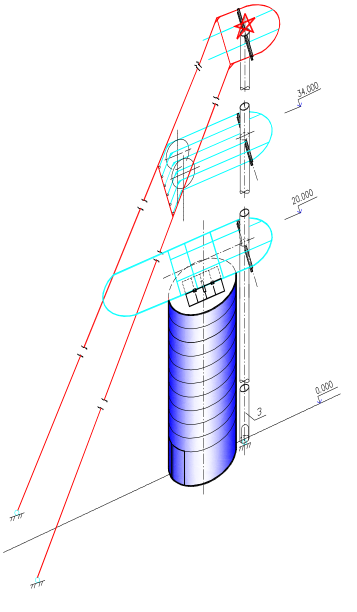


Fig. 2. Sketch of a multi-purpose winding tower for the operation period:
1) - jib; 2) – central tubular pole; 3), 4) pulley pad; 5) ring brace 6) rig

Fig. 3. Prototype of a steel multi-purpose winding tower for the mining period

The winding tower has pulley pad, including frame jib 1 (see. Fig. 2) of variable cross section, central tubular pole 2, pulley pads 3 and 4, ring brace 5 and round-shape rig 6, leaned against wellhead via curb.

The developed structure of the winding tower has advantages versus the traditional decisions of the 4-poles winding towers of the rig type as follows:

- high tightness of box-like and circular sections of pulley device allows avoiding penetration of coal dust, and hence increases their resistance to corrosion;
- lack of bracings on the jib frame 1 facilitates easy access for inspection and protection of elements and components of the structure, as well as eliminates the accumulation of coal dust, slag and lube at the nodes of connection;
- frame machine 6 does not transmit load from hoist on wellhead of the shaft and has no rig base and braces, therefore, the cost for their maintenance is not required;
- a railing in the shape of barrel significantly improves the airtightness of the machine, and also reduces the amount of undesired joints compared with traditional fencing panels;
- free space inside of the central tubular pole allows you to place a hoist for equipment and head-frame service, what creates more comfortable and safe working environment;
- hoist structure device inside the tubular rack 2 can not only improve the service conditions, but also eliminates the need for traditional metal ladders along the jib located in the area of hoist ropes, what is undesirable for safety reasons.

Since the mine winding towers experience various types of dynamic loads (seismic load, dynamic load of equipment, wind pulsation, emergency load), an important factor for their calculation is limited by the natural oscillation frequency.

The proposed structure (see Fig. 2) is designed considering the limits by the natural oscillation frequency, upholding of which characterizes the dynamic equilibrium of the structure. If required, the ring brace 5 can be regarded as a damping element by changing its the mechanical parameters we can displace resonance points of the vibrational system to the direction of frequencies (up to 4 Hz), which are safe for the working personnel.

3. Conclusion

The found technical solution reflects the essence of the new approach to finding effective design solutions that takes into account the requirements of durability and safety, along with the requirements of reliability and economy.

Thus, when designing winding towers operating under difficult conditions, the choice of a rational design itself is an effective preventive measure to improve industrial safety, reliability and optimal physical resource.

4. Reference

[1] Lobkov S.V. Defects and damage of rig type winding towers after a normal period of operation / S.V. Lobkov, A. Zapol'skiy // Labour Safety in Industry, 2012. - № 4. - 14-15p.

[2] Patent 2120013 C1 (RU), 6E 04 H 12/26. Multifunction device for mining and operation of vertical mine shafts / E.G. Kassikhina, V.V. Pershin. - № 97110900; Claimed 26.06.97; Published 10.10.98., Bull. # 28.

Engineering and process design solutions for the vertical shaft completion

Qiao Weiguo[1,2], Pershin V.V.[3], Kassikhina E.G.[3], Butrim N.O.[4]

1.Shandong University of Science & Technology, Qingdao 266510,China;2.Shandong Provincial Key Laboratory of Civil Engineering Disaster Prevention and Mitigation, Qingdao, Shandong 266510, China;3.T.F. Gorbachyov Kuzbass State Technical University, Mining Institute, 650000, Kemerovo, Russia;4.leading specialist, Department of capital construction and investment activities of OOO «UK Mechel-Mining» (LLC "Management Company Mechel-Mining"), 125993 Moscow, Russia

Abstract

The comprehensive approach including the combination of advanced and new technical solutions with the use of modern technology opportunities providing the real possibility to reduce the vertical shaft construction labour inputs, costs and time.

Keywords: vertical shaft completion, decrease of transient periods by means of application of efficient equipment and multifunctional steel angle headgears.

1. Introduction

Currently the tendency to reject the construction of vertical shafts is dominated in the design of new Kuzbass mines – the preference is given to the slop mining.

This tendency is determined by some reasons:

- significant construction time of vertical shafts - 50-60% of the total duration of mine construction;
- high cost of construction of vertical shafts - 25-30% of the total capital investment;
- lack of qualified staff due to the elimination of the most part of the specialized mine construction organizations;
- lack of engineering base in this field in Russia.

It is obvious that only a comprehensive solution of these tasks will help to select the optimal solution, which includes the study of process parameters, sinking schemes, mechanical means and equipment.

The analysis of time schedules (Fig. 1) for the construction of vertical shafts shows that at least 2/3 of the total duration of the work $T_{общ}$ is spent on shaft completion $T_{общ}$, equipment $T_{арм}$ and reconstruction $T_{переход}$ before the operation.

$$T_{переход} = T_{демонтажа\ прох.\ копра} + T_{монтажа\ постоянного\ копра}$$

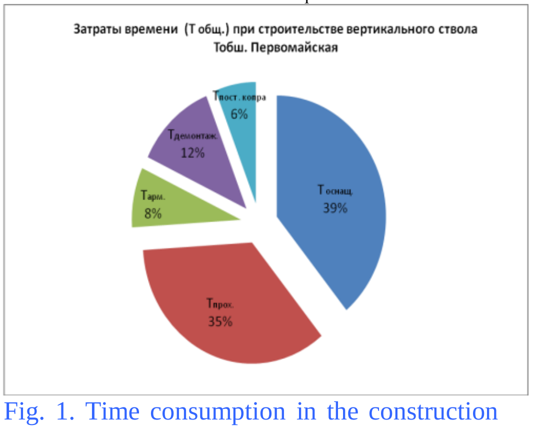


Fig. 1. Time consumption in the construction of vertical shafts

Time consumption ($T_{общ}$) in the construction of "Pervomayskaya" mine vertical shaft

sinking time

shaft equipment time

sinking headgear dismounting time

permanent headgear mounting time

completion time

For the small-depth vertical shafts (up to 300 m) the relative proportion of time spent on completion, equipment and reconstruction will be more. Therefore, a high average operation rate of sinking the extended part of the shaft does not significantly affect the shaft construction time shortening.

The real evaluation criterion of the vertical shaft construction time is the *calendar rate* determined taking into account the full scope of shaft construction works for the period from the beginning of its completion up to the horizontal drivage.

So, in Kuzbass, with the average operation rate of the vertical shaft sinking more than 50 m / month, the average *calendar rate* does not exceed 10 m / month (this rate becomes lower when the shaft depth is being decreased).

Consequently, reducing the period of shaft preparation for sinking operations is the main reserve to reduce the overall length of shaft construction in general.

For the shaft construction it is necessary to make some preparations. They are the following basic steps: surface preparation and drilling the technological part of the shaft (including the mouth); surface completion for shaft sinking, including the mounting of the headgear; shaft sinking; shaft equipment; shaft reconstruction for the construction of horizontal and slope workings, including the dismounting of the headgear for the period of sinking and permanent headgear installation.

Shaft mouth and pre-sink construction is generally regarded as an isolated construction object and equipped with the equipment other than the equipment used for the construction of an extended part of the shaft.

First, the 3-4 m depth pit for shaft mouth is excavated with an excavator on the shaft construction site. Then the permanent reinforced-concrete support for shaft mouth is erected. Also the construction of headgear foundation (sinking headgear “Sever-2” or permanent headgear) with the following pit backfilling is performed.

Further, to place the technological equipment into the shaft (sinking stage, falsework, rock-loading and drilling machines) the 35-55 m depth - depending on the type of equipment used and accepted technological scheme – the pre-sink is conducted. In Kuzbass conditions, the pre-sink is usually constructed in the bedrock by drilling and blasting method.

Blast-hole drilling is done manually by drills (ПП-63, ПП-54); the blasted rock is loaded with the grab КС-3 into the 1m^3 capacity bucket suspended on the crane. Concreting skip is 2.0 m.

On the surface the rock is loaded into dump trucks with its further transportation to a waste heap.

As already mentioned, domestic mine construction organizations use hand-held drills for hole drilling during the pre-sink construction. This is due to the fact that the machine БУКС-1м (Fig. 2), which is usually used in Russia as the only equipment for drilling during the construction of vertical shafts, is applicable only after a complete pre-sink sinking.

To bring the machine into operation it is necessary to make its central string rest upon the shaft face and the loading machine telpher, the assembly of which in its turn is possible only after the construction of the sinking stage. Such dependence of the equipments on each other does not allow achieving high rates of sinking in the construction of pre-sink that negatively impacts on the calendar rate of shallow 200-300 m depth shaft construction, as the length of the pre-sink at such shaft depths reaches 20-25%.

Currently, there is equipment for drilling for the vertical shaft sinking (Fig. 3) that can be used both for vertical shaft sinking, and for pre-sink sinking.

The proposed machine SJZ (China) does not depend on other equipment (loader, sinking stage) used shaft sinking. To be brought into operation it rests upon the bed walls. One drilling machine replaces the performance 15-18 hand-held drills.

The application of SJZ machine allows passing the pre-sink in a shorter time, and with the help of equipment that is used for further sinking of the extended part of the shaft. This reduces the transition from pre-sink construction to the construction process of the extended part of the shaft.

Thus the use of inefficient equipment is avoided and the time of transition from pre-sink construction to the construction of extended part of the shaft is reduced.

In the Russian mine construction practice the domestic analogue was used - drilling machine СМБУ-4м (KuzNIIshakhtostroy), which unfortunately is not currently produced.

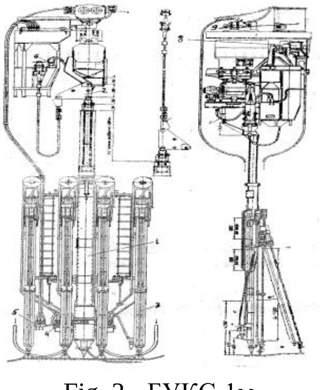
The current situation has led to a significant rise in the cost of equipment (see Fig. 2, 4), required for the construction of vertical shafts, which negatively affected their already high cost. Problem can be solved in two ways: either develop domestic engineering, or find less expensive options abroad (see Fig. 3, 5). Comparable figures of to the problem solutions are shown in Table 1.

One of the possible ways of increasing the technical and economic performance of the preparatory period is maximum use during the construction of permanent buildings and utilities of the mine.

However, the experience in the construction of new mines shows that the use of permanent buildings and equipment does not exceed 50% of the design. As it can be seen from the diagram (see Fig. 1), the duration of vertical shaft completion is up to 60% of the total duration of the shaft construction also because of the interruptions in the work associated with assembly-disassembly of sinking headgear and assembly of the permanent headgear.

Noteworthy, in our opinion, is the proposal for the combination of various functions in one device during shaft sinking and exploitation.

Table 1. Comparable figures

 Fig. 2 - БУКС-1м
Quantity of drilling machines: 4. Mass: 7 t. Drive: pneumatic. Used in technological scheme: combined Cost: 18,742 mln. roubles (Yasinovataya engineering plant)

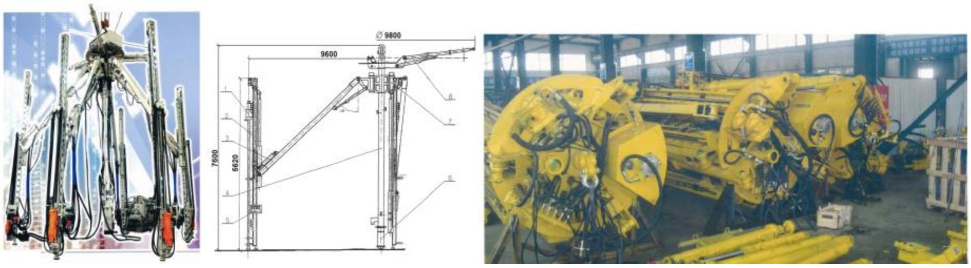


Fig. 3. - SJZ (China)

Quantity of drilling machines: 5-6.
Mass: 5,3-7,8 t.
Drive: hydraulic/pneumatic
Used in technological scheme: combined/parallel
Cost: 8,475 mln. roubles (TS&T CO. LTD China)

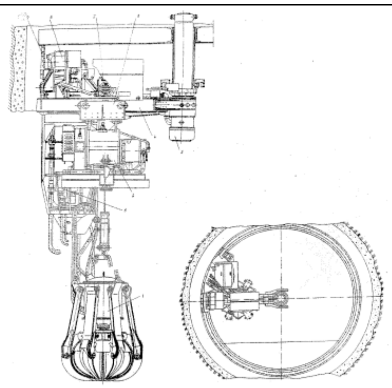
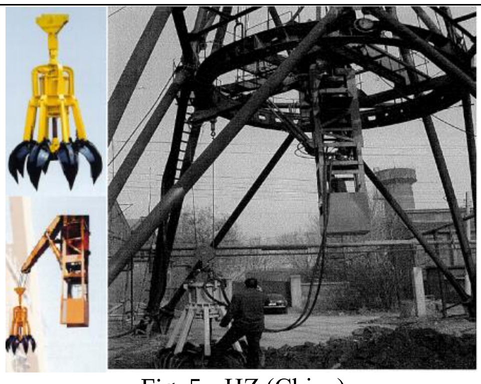
 Fig. 4 - КС-2/40	 Fig. 5 - HZ (China)
Performance: 2,3 m^3/min Bucket capacity: 1 m^3 Масса: 16 т. Drive: pneumatic Cost: 28,728 mln. roubles (Yasinovataya engineering plant)	Performance: 2,3 m^3/min Bucket capacity: 1 m^3 Масса: 6 т. Drive: hydraulic/pneumatic Cost: 5 mln. roubles (TS&T CO. LTD China)

Fig.6.Multifunctional adgear. Model for the periodof mouth drilling

Fig.7.Multifunctionaleadgear. Model for the periodof inking epy extended part of the shift

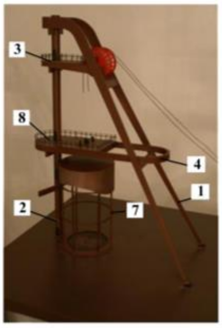


Fig.8.Multifunctionaleadgear. Model for the period of exploitation

The department "Construction of underground structures and mines" of KuzGTU developed the steel multifunctional headgear [2], the distinguishing feature of which is the combination of fixed set of design elements in one ground device used throughout all the period of shaft construction and operation and replaceable units for its operation at sinking period (Fig. 6, 7, 8).

The idea is to develop individual headgear design [3] on the basis of the unified hardware set (box-shaped and tubular structures of variable cross section), consisting of three main functional units: ***the main bearing block, a temporary constructive block, additional constructive block.***

The main bearing block providing the permanent lifting functions consists of under-wheel device comprising a cross brace 1 (see Fig. 6) of variable box-shaped and tubular cross section, center column 2, which can be replaced by a central tubular portal,

permanent under-wheel platforms 3 (one or two, depending on the lifting scheme), and the annular brace 4.

It is mounted on the stage of shaft completion for the pre-sink drilling immediately after the construction of the shaft mouth and the backfill (if the headgear foundation is ready) and is used at all stages of the shaft construction and operation.

Temporary constructive block (see Fig. 7), provides the sinking functions and consists of under-wheel sinking stage 5 on the basis of the annular brace 4 and the unloading machine 6.

It is added to under-wheel device when sinking the extended part of the shaft. Dimensions of under-wheel sinking platform allow converting it further for shaft equipping in the short term.

Additional constructive block that provides exploitation operations consists of a carrier frame machine 7 (see Fig. 8). Frame machine 7 is set to go to the construction of horizontal workings after dismounting of unloading machine 6 and the sinking under-wheel platform 5 is converted into a damper platform 8, necessary for permanent lifting.

Since the proposed headgear combines the functions of sinking and operation, such steps as the headgear dismounting for the period of sinking and the permanent headgear installation. At the same time the transition periods including the transition from the pre-sink construction to the construction of the extended part of the shaft, the transition to the equipment, as well as the transition to the construction of horizontal workings, are reduced to a minimum. Thereby the calendar rate of shaft construction is increased.

The proposed design is characterized by a reduced range of metal castings for the headgear manufacture and has 25 - 35% smaller metal content compared to traditional solutions for similar conditions, as well as allows creating a more comfortable working environment for the maintenance of headgear equipment at the expense of lift construction inside the central tubular column.

The dimensions of the proposed headgear allow putting into the shaft the sinking stage and the bottom-hole formwork which have been already mounted on the surface, as well as to store and maintain the drill in it.

2. CONCLUSIONS

The construction of the mouth of the shaft and the pre-sink should not be regarded as the construction of the isolated objects. The equipment for the pre-sink construction should be linked to the maximum extent with technology of construction of its extended part.

The practical experience of recent years has shown that the greatest efficiency of vertical shafts construction is achieved in the case when transition periods including the transition from the pre-sink construction to the construction of the extended part of the shaft, the transition to the equipment, as well as the transition to the construction of horizontal workings, are reduced to a minimum

The proposed technical solution for the vertical shaft completion using the multifunctional headgear will develop the best way to complete the vertical shaft constructions, which allows to reduce the cost and duration of mining operations – in 1.3 times, the complexity - in 1,7 times, to shorten the duration of the preparatory and transition periods in 1.2 times as compared to conventional construction methods, as well as create a more comfortable and safe environment for the headgear maintenance.

The design is protected by the Russian Federation patent. The methods of its calculation are also developed [4].

3. REFERENCES

[1] Baronskiy, I.V. Construction and deepening of vertical shafts / I.V. Baronskiy, V.V. Pershin, L.V. Baranov. – M. : Science, 1995. – 328 p.

[2] Patent № RU 2120013 C1. Steel multifunctional headgear for the construction, operation and deepening of vertical shafts / E.G. Kassikhina, V.V. Pershin.

[3] Pershin, V.V., Kassikhina, E.G. New concept of multifunctional steel headgear // Coal, 2001. - №2. – P. 11-14

[4] Kassikhina E.G. substantiation of parameters and development of the method for the multifunctional steel headgear calculation / E.G. Kassikhina, V.V. Pershin, N.F. Kosarev. – KuzSTU, 2012. - 29 p.

Economic and technological criteria of choosing the support for construction of mine workings

Song Weijie[1], Pershin V.V.[2], Masaev Yu. A.[2], Masaev V.Yu.[3], Qiao Weiguo[1]

1. College of Civil Engineering and Architecture, Shandong University of Science and Technology, Qingdao, Shandong 266510, China; 2.Department of underground structure and mine construction, Mining Institute of T.F. Gorbachev Kuzbass State Technical University, 650000, Kemerovo, Russia; 3.Department of enterprise economy and management, G.V. Plekhanov Russian Economic University, Kemerovo Institute, 650000, Kemerovo, Russia

Abstract

The problems of rock outcrop self-sustainability maintenance in mine construction are considered. The basic requirements to the applied types of supports are formulated. The new design solutions for some kinds of supports are proposed.

Keywords: mine opening; support; sustainability; rock outcrops; bolt; roof collapse.

1. Introduction

Rockmass is the concentration of various mechanical processes that depend on a number of factors. A feature of such processes affecting mining is the increase of stresses in the marginal rock mass after its mining. The certain values of those stresses being achieved, the marginal rock mass begins to failure losing its bearing capacity. Loss of bearing capacity may occur both as a result of the carrier plastic flow, and as a result of brittle rock fracture.

Mechanical processes that occur in the marginal rock mass often lead to unintended consequences in the form of rock collapse into the working and some geodynamic phenomena. Such processes have repeatedly occurred in coal mines. To make the reasoned choice of ways and means to prevent these phenomena it is necessary to estimate the degree of development of mechanical processes in the specific geomechanical conditions.

One of the major problems of rock mechanics is the prediction, evaluation and control of self-sustainability of rock outcrops during construction of mine workings.

2. Characteristic of the work

Predicting the stability of unsupported mine working at the deterministic formulation of the problem is reduced to the verification of the condition:

$$\sigma_{\partial} - \sigma_{сж} \leq 0,$$

wherein σ_{∂} – the main maximum stress, acting at the unsupported contour of the working; $\sigma_{сж}$ – uniaxial compressive rock resistance.

The various variants of this condition are associated either with the specification of values σ_{∂} и $\sigma_{сж}$, for which whole system of rates reflecting various factors is used, or with different ways of comparing the stresses and strength properties of rocks. When the specified condition is fulfilled the outcrop is classified as self-sustainable. A failure of this condition is due to the limit equilibrium area formation in the working vicinity and the rock outcrop is considered as unsustainable. On the basis of this condition, various authors have developed a series of numerical criteria which allow classifying the rock outcrops according to the self-sustainability degree.

The self-sustainability of outcrops is strongly influenced, under otherwise equal conditions, by the properties of the host rocks and their water content. Studies conducted in the 700 m length airway of "Raspadskaya" mine (Kuzbass) with 13.3 m^2 cross-sectional area, in the adjacent areas of dry and water-flooded rocks showed the following.

The water intrusion into the seam roof rocks leads to a sharp decrease of the outcrop self-sustainability, intense stratification and rock fall. Flooded and wet roof rocks usually lose self-sustainability in 1-3 hours after their outcropping on the area of 2.5-3.0 m^2, while the dry rocks, under otherwise equal conditions, maintain self-sustainability within 24-30 hours or more.

Rock falls occurred unevenly along the exposed surface, they were most often observed in the middle part of the roof and near the sides of the working. The depth of the rock falls since the moment of their outcropping up to time of the support setting ranged from 0.1 to 0.4 m, the area of rock falls - from 0.2 to 0.4 m^2. In the course of mining operation the number of rock falls increase, which leads to the destruction of supports and the sufficient size doming, the elimination of which leads to significant economic costs.

On the basis of carried out laboratory and field studies the classification of roof rocks in the workings located outside the area influenced by mining operations was developed.

The classification is based upon the values of the outcrop area and the duration of its self-sustainable state, because these parameters have the greatest influence on the choice of the support type and the justification of timbering plan. According to these criteria the roof rocks of constructed mine workings were divided into seven groups: I - very self-sustainable; II - self-sustainable; III - above average self-sustainability; IV - average self-sustainability; V - below average self-sustainability; VI - self-unsustainable; VII - very self-unsustainable.

The developed classification allows: 1) to solve problems of the possibility and necessity of mining operations without or with timbering; 2) to find out the detachment of permanent support from the coal face, which is extremely important when mining under high-speed schedules; 3) to solve the problem of the necessity of protective support application in the face space of workings; 4) to pre-choose the type of permanent support in the workings.

The existing methods used to ensure the mining working sustainability can be divided into three groups depending on the nature of their influence on the mechanical condition of rock mass: active (protection); passive (support) and combined (maintenance). The main way to ensure the self-sustainability of mining workings is the support.

In this regard, a special attention is paid to the correct choice of support for different geological conditions. The support of mine working should be integrated with the surrounding rock mass and have adequate ductility and bearing capacity. However, all these conditions are not always met. The analysis shows the common use of such support kinds which have become traditional for certain mines and they are often applied, because the employees of these mines already accustomed to them. But they are not always cost efficient and do not always correspond geological conditions. At the same time, workings conducted through self-sustainable rocks are sometimes supported by unreasonably expensive linings.

One effective means of radical solutions to the problem of rational support and maintenance of mine workings is a combination of load bearing supports and supports which allow using, in varying degrees, the bearing capacity of the rock mass by creating a uniform system of "support - rock mass." Using the rock mass as a load-bearing structure, it is possible to reduce the material intensity and the cost of supports, without losing the self-sustainability of the working. From an economic point of view it is necessary to be guided on the use of lightweight types of supports, but the final choice should obviously be based on its reliability.

A very important factor is the quality of marking the working contour during its construction. If the contour of the working is uneven (as in the case of drilling and blasting method of mining), the stress concentration around the working will be completely different from that of the smooth contour (as in the case of cutting method). However, the rocks destroyed by explosion, although less stable and exposed to larger displacements then the solid rocks in the course of rock mass deformation (due to loosening effect), are discharged from the stresses and form together with the supports the system of forces reacting upon the rock displacement. In this case, the contour deformation caused by the shattering, occur before support setting. Therefore, from this point of view, drilling and blasting method of working is more favorable than the cutting one.

It is known that stable rocks when the stresses do not exceed lasting properties of rocks and the deformation is of elastic kind, the contour is stable and the support and the bearing structure are not needed. In those cases when there is the inelastic deformation area around the working, it is necessary to set the compressible support to provide the rock with the possibility of some deformation, otherwise the support can be destroyed.

When considering the system "support - rock mass" in various geological conditions, we outlined two main support modes: the mode of given load and the mode of interdependent deformation (the support and the rock mass act together, the load on the support is determined by its deformation with deformed rock masses). The main support parameters are its compressibility and load-bearing capacity. These modes can be mixed and combined. For example, first the support can only support the exfoliated rocks of the roof and operate in the mode of given load, and then due to the rise of deformation of the overlying layers can be switched to the mode of interdependent deformation.

Years of experience in studying the mechanism of interaction of the system "support - rock mass" have given the opportunity to form the basic requirements for mine support, which are the following:

- To ensure the shape keeping and the cross section dimensions of the working throughout its operation time;
- Not to require an increase in the working cross section in the course of its construction and operation;
- To have a low resistance to the movement of the air flow when airing;
- To have a minimum cost of its construction and maintenance.

Taking into consideration the facts given above, we have developed some support options for the construction of mine workings in various conditions.

Currently the roof bolting of various modifications is widely used. The disadvantage of the known roof bolting structures is that they perform only one function - the role of the supporting structure that supports a specific rock mass of the marginal space of mine workings. However, while mining we meet various conditions of rock occurrence - bedding, fracture, multiple degree of disturbance. If the production is carried out using drilling and blasting operations, the 1.0-1.5 m depth rock-fracture zone is created within the marginal rock mass due to the explosion energy, and it significantly reduces the self-sustainability of rock outcrops.

In such cases it is necessary to create conditions for the stabilization of the geological structure of the rock mass behind the contour of the working. This is the second function that the roof bolting must have. Such a function, to some extent, should be performed by pre-stressed rope bolts rope. But the significant drawback in such constructions is the complexity of the multi-layer metal rope tensioning when installing bolts. We have developed a fundamentally new bolting type – expanding hold-down [1], which consists of a metal rod 1 (Fig. 1), 2 metal wedge inserted into the slot on the upper end of the metal rod, two ribbed half-couplings 3, 4 connected by mounting ring (fixing device may have any other structure). The spring 5, the design parameters of which are taken depending on the length of the bolt and the structural state of the rock mass, is fixed on metal rod 1.

The cylindrical sleeve 6 is fixed to the lower end of the spring. The cylindrical sleeve 6 has the thread on the outer surface on which there is the support plate 7 in contact with the rock mass 8 and tensioning nut 9.

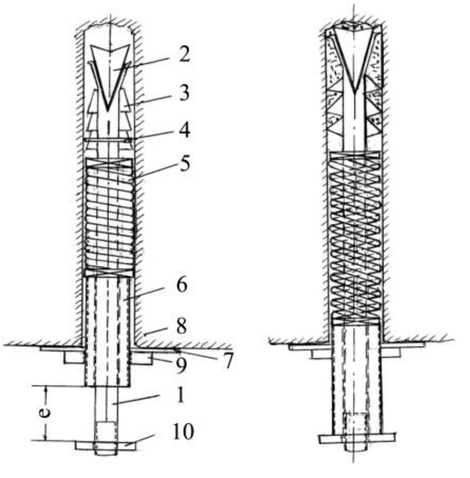


Fig. 1. Expanding hold-down bolt

At the lower end of the metal rod the restrictive nut 10 is set by a threaded connection. The restrictive nut fixes the stretching length of the spring 5 and limits the move of the cylindrical sleeve 6. The magnitude of the limiting distance *L* is calculated when developing the plan of rock outcrop supporting, taking into account the structural condition of the rock mass and the magnitude of the required "contraction" of it depending on the degree of fracturing and disturbance.

The anchor is inserted into the hole and fixed with a metal wedge 2 and ribbed half-couplings 2 and 3 at the bottom of the hole. For a more durable fixing of the head part of the bolt the polyester resins ampoules were used. After fixing the bolt in the hole, the tensioning nut 9 is screwed onto a cylindrical sleeve 6, which is shifted along a metal rod 1 to the lower position as far as the restrictive nut 10, stretching the spring, while pressing the support plate against the supported rock mass.

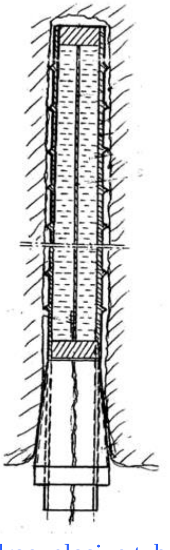


Fig. 2. Hydroexplosive tubular anchor

During the operation, a stretched spring tending to compress compresses broken rock layers, reducing cracks and preventing their further development, which greatly increases the stability of rock outcrops throughout the operation time of mine workings.

In the construction of mine workings in inmonolithic rocks undisturbed by fractures hydroexplosive tubular anchor is recommended (Fig. 2) [2]. It is made in the form of a metal pipe on the outer surface of which the jagged juts are situated.

The ends of the tube are closed with sealing plugs, and the interior of the tube is filled with water, detonating cord with EB passing through it.

Preliminary anchor fixing in the hole until the moment of detonating cord initiation is made by means of special flare nut [3].

After placing hydro explosive tubular anchors in the holes the electric detonators are ignited.

Upon the detonation of the detonating cord in the water, a hydraulic shock occurs and the compressive stresses act on the metal pipe walls throughout its length. Due to this, the wall of a metal pipe expand and press against the rock, but the jagged juts incorporate into the hole walls, providing effective and reliable fixation of the anchor in the hole.

In combination with constant roof bolting of any design, we have developed a temporary enclosed support (Fig. 3 and 4) [4, 5, 6].

The aim of temporary enclosed support - protection from rock piece falls after the explosion of the set of blast-hole charges in the course of shattered rock loading and face area treatment until the temporary and permanent support setting. This support consists of a sliding cantilever beams manufactured from special profile SVP with protective overlap in the form of a metal grate, fixed

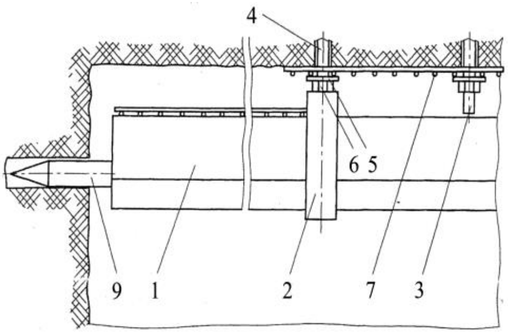


Fig. 3. Sliding temporary enclosed support

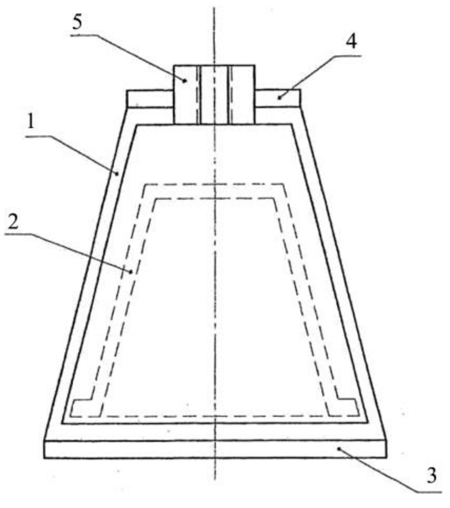


Fig. 4. Support element for sliding support

On the end parts of roof bolting with special support elements is made of bent parts in the form of a trapezoid, and repeats the shape of cantilever beams manufactured from special profile SVP. The bent parts are connected by horizontal upper and lower platforms. The upper platform has a nut screwed onto the cap wires of the bolting. The support elements are screwed and easily transferred to the following series of newly installed bolts.

The sliding temporary enclosed support is easily erected on the roof bolting and moves without any mechanisms, and the form of support elements, repeating the form of SVP cantilever beams prevent their displacement and inversion during the operation, which increases the safety of the miners.

Conclusion

The application of the designed lightweight kinds of supports allows reducing the material consumption and the cost of mine workings ensuring the required bearing capacity of the system "support – rock mass" and safety of miners.

References

[1] Patent № 138709, Russia, МПК E21D 21/00. Expanding hold-down bolt / Yu.A. Masaev, V.Yu. Masaev, S.A. Sokolov. Published 20.03.2014.

[2] Patent № 122697, Russia, МПК E21D 21/00. Hydroexplosive tubular anchor / Yu.A. Masaev, V.V. Pershin, V.Yu. Masaev, E.V.Kurekhin. Published 10.12.2012.

[3] Patent № 128243, Russia, МПК E21D 20/00. Device for preliminary hydroexplosive tubular anchor fixing in the borehole / Yu.A. Masaev, V.Yu. Masaev. Published 20.05.2013.

[4] Patent № 76073, Russia, МПК E21D 19/04. Temporary enclosed support when constructing permanent roof bolting / S.N. Bakanyaev, E.V. Parshikova, Yu.A. Masaev, M.D. Voitov. Published 10.09.2008.

[5] Patent № 102679, Russia, МПК E21D 19/00. Temporary enclosed support / V.V. Pershin, Yu.A. Masaev, M.D. Voitov, V.Yu. Masaev, E.V. Parshikova. Published 10.03.2011.

[6] Patent № 107282, Russia, МПК E21D 19/00. Support element for sliding support / Yu.A. Masaev, V.Yu. Masaev, E.V. Parshikova. Published 10.08.2011.

Constructions Parameters Updating of Protecting Apron Under Deepening of Vertical Shafts

Pershin Vladimir V.[1], Kopyitov Aleksandr I.[1], Voitov Mikhail D.[1], Wetti Akhmed A.[1], Zhuk Ivan V.[2]

1.Department of Underground Construction and Mining T.F. Gorbachov Kkuzbass State Technical University, 650000 Kemerovo, Russia
2.Llc "Sibgorkompleks – Engineering" 654066 Novokuznetsk, Russia

Abstract: New construction wedge safety shelves are offered. The principle of work engineering construction, its advantage and economic expedience of introduction in production are described.

Keywords: shaft, depending, safety shelves.

The Gornaya-Shoriya branch of Joint Stock Company "Evrazruda" is located in Tashtagol area of the Kemerovo region in the village Sheregesh, the company develops by means of underground method the Sheregesh iron ore deposit and performs the initial concentration of ores. Mining was started in 1953.

The deposit was excavated by six vertical shafts of various purposes. "Skipovoy", "Novo-Kletevoy" shafts are located on the Western flange; "Glavnyiy", "Vostochnyiy", "Lesoperepusknoy" shafts are located on the East flange; and in the center there is "Vozduhovyidayuschiy" shaft. To develop field reserves and increase the productive capacity of the mine, the institute "Sibgiproruda" realized the project of reconstruction of the mining enterprise. The important step of this project is skip shaft deepening (Fig. 1).

"Skipovoy" shaft is put down to the level of +115 m, inside diameter is 6,5 m. It is designed to ore and rock mass hoisting from the mine. It is equipped with two skips, carrying capacity of which is 50 tons and two skips with carrying capacity of 15 tons. Since the shaft is productive, the deepening was conducted from advanced borehole.

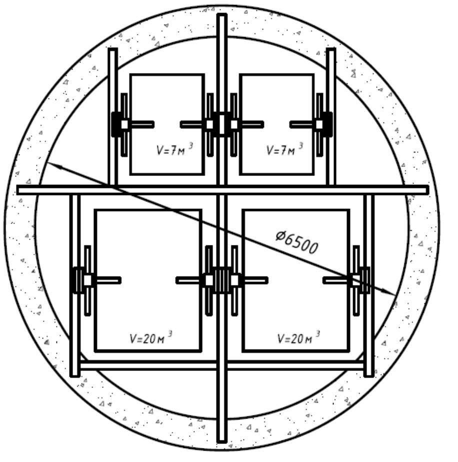


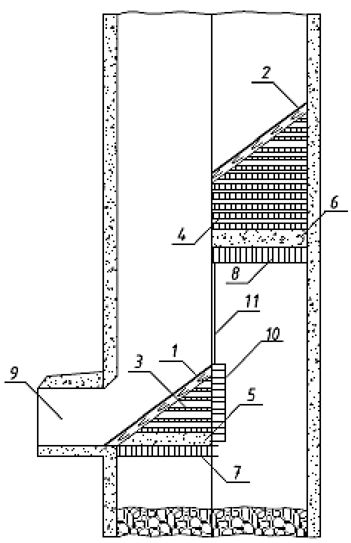
Fig. 1: "Skipovoy" shaft section

According to mine safety decisions under simultaneous shaft deepening and permanent stationary hoist, the face of deepening shaft area should be isolated from the stationary hoist by means of protective device, which must meets the following requirements:

– high protection reliability of deepening areas of vertical shafts from all kinds of accidents, associated with the fall of heavy bodies in the shaft during the lifetime of the deepening works;

– minimum construction period and the subsequent development of the sollars, as they affect directly the duration of shaft deepening and construction of new levels.

In connection with the developing of existing levels of "Sheregeshskaya" mine for development and preparation of underlying levels, "Skipovoy" shaft must be deepened from +115m. to – 85m. Full stop of the enterprise for the time of drivage, erection and shaft equipment could result in the loss of production capacity of the mine ore extraction and mass job cuts. In this regard, after scientific literature analysis, analysis of existing methods of shafts deepening and types of safety devices analysis, the staff of CUF and M department of T. F. Gorbachev KuzSTU together with specialists from the design organization LLC "Sibgorkompleks – engineering" developed and implemented a new design of protective device (Fig. 2). The apron is represented by two parts, shifted in elevation, each of which has an inclined baffle wall *1*, *2*, dampening element *3*, *4*, the buffer distributive - weighting concrete plate *5*, *6*, horizontal support beams *7*, *8*.



1, 2 - inclined baffle wall; 3, 4 - dampening element; 5, 6 - distributive - weighting concrete plate; 7, 8 - horizontal supporting beams; 9 - baffle stable hole; 10 – vertical wall of supporting beams; 11 - divide wall.

Fig. 2 : Wedge-type protecting apron (The Russian Federation Patent №120706)

Inclined baffle surface 1 of apron bottom is included in the baffle stable hole *9*, and a series of support beams *10* forms a vertical wall, holding the elements of bottom of the device from the displacement to the shaft center. The baffle wall *11* connects the two parts of the apron, thereby blocking the section completely [1].

The upper part of the structure is designed for high impact load and is built up under the section of ore skips and lower part is built up under the section of a smaller in size rock skips.

A wedge protecting apron works in the following way. Inevitable spile, and sometimes the whole mass of the ore skip falls on a metal sheet of inclined surface *2*, it rolls down the inclined surface *1* and enters the stable hole *9*. Spile from the rock skips falls on inclined surface 1of the apron bottom and also is accumulated in the baffle stable hole *9*.

Because of the fact that the impact load from the direction change is ten times less than the complete extinction of the kinetic energy of falling bodies, it is transmitted through the damping element on buffer distributive-weighting concrete plate, and then it is transmitted partially to the support beams, to the barrel walls in the upper part of the protective apron and to the vertical wall from the support beams *10*.

In order to reduce material and labor costs, shortening installation and dismantling period the same group of authors developed a design of a bottom of the wedge protective apron, being built under the rock skips section (Fig. 3), which includes an upper inclined surface 1 from the metal sheet, buffer distributive - weighting concrete plate *2*, *3* dampening chock and also is laid on the bearing beam *4*, stable hole *5* and vertical divide wall *6* at the shaft axis [2].

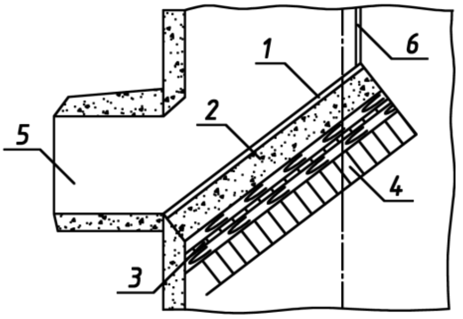
The difference is that a buffer plate 2, a dampening chock 3 and supporting beams

4 are arranged in the surface, parallel to the upper inclined surface 1.

This wedge protecting apron works in the following way. Rock spile from a vehicle falls on upper inclined surface 1 and rolls down in to a stable hole 5, and is removed from it.

The application of the proposed design of the protecting apron according to the Gornaya-Shoriya branch of Joint Stock Company “Evrazruda” experts allowed achieving the following technical and economic indicators:

- the complexity of installation and removal of the protecting apron is reduced;
- working time on the construction of the apron is reduced to 23 days in comparison with the planned period;
- by reducing material consumption the economic efficiency in the amount of 400 thousand rubles is achieved;
- the uninterrupted duty of hoist and thereby the real profit of the company is increased of 68 million rubles;
- the stable work of the enterprise is provided until 2050.



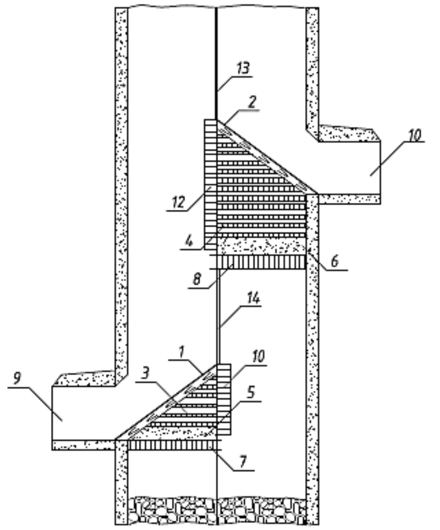
1- upper flaring wall; 2 - buffer distributive - weighting concrete plate; 3 - dampening element; 4 - supporting beams; 5 - stable hole; 6 - divide wall

Fig. 3: Wedge protecting apron (The Russian Federation Patent №133198)

The experience of operation of protecting aprons in the reconstruction process of the Gornaya-Shoriya branch of Joint Stock Company “Evrazruda” will improve the previously proposed design of the protective device (Fig. 4). It also is consisted of two parts, shifted in elevation, but turned around each other by 180°, the parts have the same inclined baffle surface 1 and 2, the dampening element *3* and *4*, buffer distributive - weighting concrete plate *5*, *6* disposed on the horizontal support beams *7, 8* [3].

Inclined baffle surface *1*, *2* are included in the stable hole *9*, *10*, and the series of supporting beams *11*, *12* forms a vertical walls, retaining the elements of the apron from the shift to the center of the shaft. The divide wall *13* is formed over the top of the apron and the divide wall *14* connects two parts of the apron.

Similarly, upper part of the structure is designed for high impact load and is built up under the section of ore skips and a lower part is built up under the section of smaller in size rock skips.



1, 2 - inclined baffle surface; 3, 4 - dampening element; 5, 6 - distributive - weighting concrete plate; 7, 8 - horizontal supporting beams; 9, 10 - stable hole; 11, 12 - vertical walls consist from supporting beams; 13, 14 - divide wall

Fig. 4: Wedge protecting apron (The Russian Federation Patent №139338)

The operation principle of the apron has not changed, namely, the inevitable spile also falls on the appropriate inclined surface 1 or 2 and rolls into additional stable hole 10 or stable hole 9, it is removed from them without mixing. The divide walls *13*, *14* prevent the rock spile enter the deepening part of the shaft.

The location of the upper part of the apron is determined by the removal conditions of the ore spile on the level of rock loading.

In the operation of protecting apron an important fact of rock mass splash in stable hole, the amount of which reaches up to 40 m^3 per day, became obvious. The proposed design of the protecting apron allows dividing ore and rock spile; this will reduce the ore losses and will increase profitability of engineering structures.

References:

[1] Utility model patent № 120706 «Wedge protecting apron under deepening of vertical shafts» Authors: Kopyitov A.I., Zhuk I.V., Voitov M.D., Morozov S. S. Applied for 26.04.12 Published 29.07.2012. Bulletin №27

[2] Utility model patent № 133198 «Wedge protecting apron» Authors: Zhuk I.V., Kopyitov A.I., Pershin V.V., Voitov M.D., Wetti A. A. Applied for 06.05.13 Published 10.10.13. Bulletin №28

[3] Utility model patent № 139338 «Wedge protecting apron» Authors: Kopyitov A.I., Voitov M.D., Wetti A. A. Applied for 28.11.2013 Published 14.03.2014. Bulletin №10

Part II

Mining theory, method and technology

Coal Deposits' Mining with High Content of Natural Radionuclide

AVDEEV Pavel B,SIDOROVA Galina P

(Mining Faculty, Zabaikalian State University,672039 Chita, Russia)

Abstract: The article considers the methods of working off of coals with high content of natural radionuclide (NRN) that allow for the coals' completeness of the getting and environmentally reducing their safety on the example Urtuysky brown coal' deposit opencast mining located in Trans-Baikal region.

Keywords: Coal, radioactivity, completeness, method of getting, charge, classifying.

1.Introduction

The most vulnerable point in the coal power is the adverse environmental impact of the coal fuel cycle. In the recent years attention is attracted the radiation pollution generated by coal industry and coal heat-electric generations.

The one of the most important problem of the coal power there are the radiation hazard of coal mining and coal heat-electric generations connected with natural radionuclide containing in coal. Sometimes the modern world underestimates this problem but this problem demands limit attention.

Coals with a high content of radionuclide are very often. According to ecologists the fuel power by coal is among the most significant pollution sources of environment by radionuclide but it wasn't taken serious steps to limit outburst of NRN with coal burning products. The serious problem is the storage of ash and slag near heat-electric generations. They occupy large areas that are not used for a long time and they are centers of heavy metal accumulation and high radioactivity.

2.Characteristic of the work

Detailed studies Urtuysky brown coal deposit allowed establishing that heavy and radioactive metals carried to certain energy grades of coal and having a real coupling with carbonaceous rocks and geological structures involved in the formation of coal deposits.

In this regard there are was an opportunity to allocate energy coals at the stage of geological exploration, characterized by certain concentrations of radioactive elements. It allows to separate the coal reserves on household (burning in furnaces), energy (burning at Heat-electric generation, hydroelectric station), complex (high content concentrations of radioactive elements and not subject to a use as energy, the possible use - gasification).

Development of technology schemes of radiation quality coal' control at the stages of the forecast availability of radionuclide in the formation of parties to prepare for burning coal to the power station , will significantly reduce the negative impact of radionuclide in coal on the environment and provide the greatest fullness of extracting it from the depths.

The uranium contamination of coal mass at several deposits predetermines the need to consider the permissible conditions for coal burning power plants and calculate the volumes of waste (disposal) of the complex coal.

The main standard parameter that determines the possibility of burning coal mass is the value of the maximum permissible emission of uranium, which for Krasnokamensk Heat-Electric

Generation approved in the amount of 3.1 tons / year.
This required the determination of uranium reserves in the loop section and the total number of coal mass with high content of uranium, by which can be adjusted by the amount of uranium in the coal with an annual averaging mode. Distribution of operational reserves of coal mass it is executed on the basis of statistical processing of coal intervals wells tested for uranium and used to calculate the average uranium content.
The criterion is the average grade of uranium content on coal horizons within the interval (bench height of 12 m) which subsequently served as the basis for drawing level quality maps for radiation parameters.
Number of stocks rock mass distribution on the ledges (level) is shown in Fig. 1.

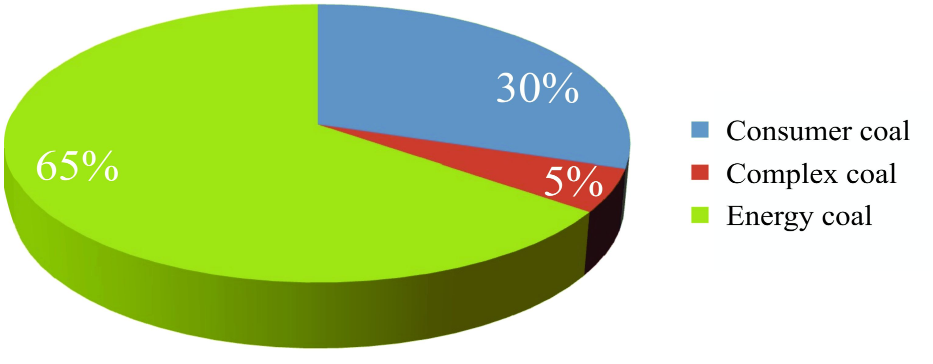


Fig . 1: Diagram of distribution of reserves of rock mass on grades of Urtuysky deposit

Radiation quality control system for coal technological stages includes two main areas:
- Quality control of coal in the planning stage through sectional level quality maps ;
- Operational control of radiation quality of coal by the mining, preparation parties products and solving the problem of its radiation safety.
The basis level quality maps on the methods of calculating the reserves of coal mass and the content of radioactive components of the coal interval wells within the horizons. Analysis of materials exploration and research allows to predict the quality of saleable coal in seams, blocks, on the horizons and mining sites .
Level maps of coal quality - this is the graphics (plans) horizons mining, coal reserves delineated and counted according to detailed and more additional investigation. Basis for the construction of maps is combined distribution plan NRN that as isohypses reflect the content of uranium, radium and thorium.
Combined plan of natural radionuclide (NRN) is based on a uniform grid equal to the distance between the lines of exploration. The isoline calculated the average content of uranium, radium and thorium, the average content of these elements is estimated approximately in each sector grid.
Border calculating blocks rebuilt by geological sections for which the reservoir area and skyline exploration longitudinal and transverse lines on the network 125h 50 m are divided into sectors. This system allows dialing the number of the optimal design data and simultaneously the area of the sector is with a height equal to the capacity of the horizon (shoulder) - 12 m.
For each sector the volume of coal is calculated and averaged qualitative indicators, combined with the plan horizon, locking and network exploration

lines (sectors) in the scale of 1:5000 and an attached table of coal quality by sector. Calculations are made in averaging mode quality, method of solving the problem of linear mixture, which is used in mining.

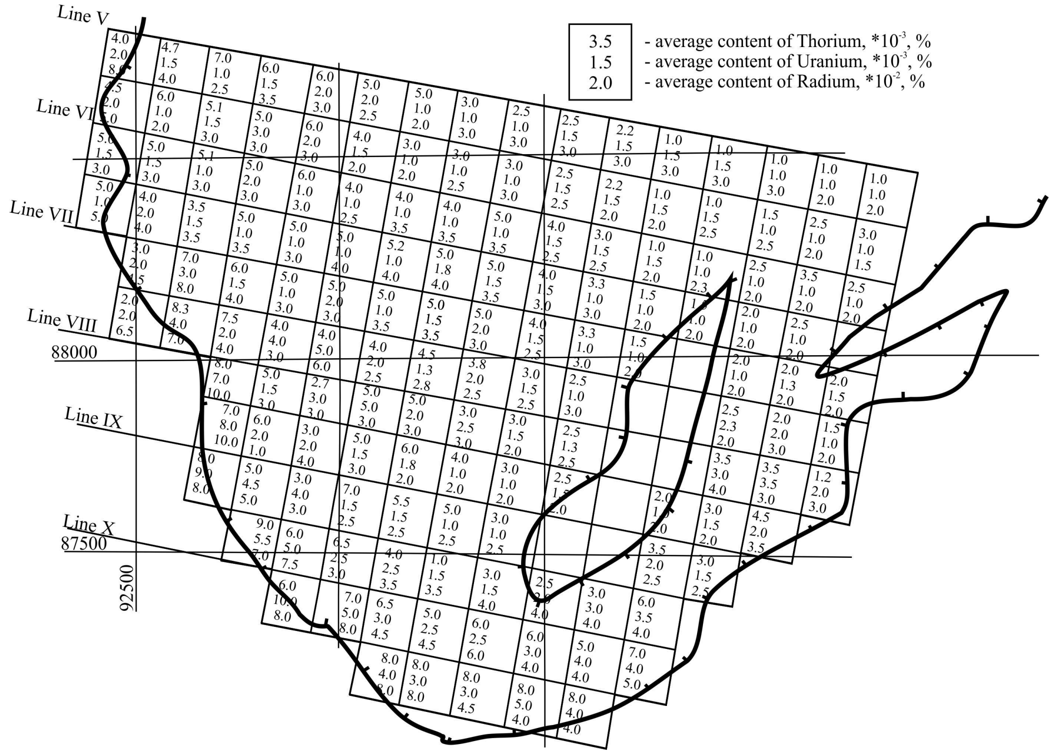


Fig.2: Combined plan NRN content in the coal stratum of by M

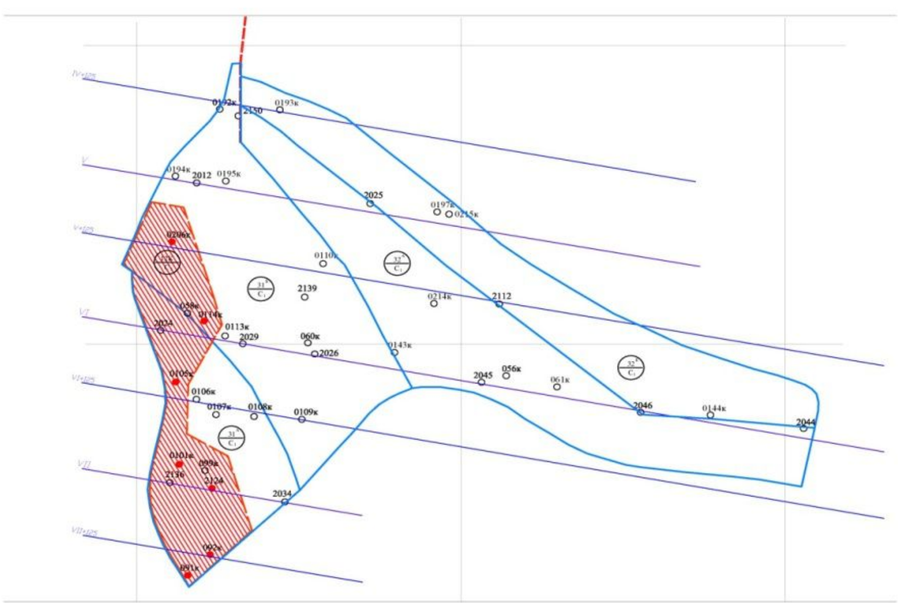


Fig.3: Scheme of the region comprehensive of coal

The coal' quality parameters calculated on the maps for planning of mining operations , conducted choice of optimal directions of work , placement of mining equipment , forecast indicators of quality in the long term .

For development of reserves based on selective and selective extraction of coal grade chosen car variant of opening , which makes it possible to manage the traffic flow of coal and generate batch of finished products required quality.

Most unfavorable to the degree of contamination within the coals are detail - explored areas planned to practice using the "election recess» (Fig. 3). In this situation, «selectively» chosen land, providing a "negative impact» on the radiation quality coal, which will continue to be practiced selective and gross ways.

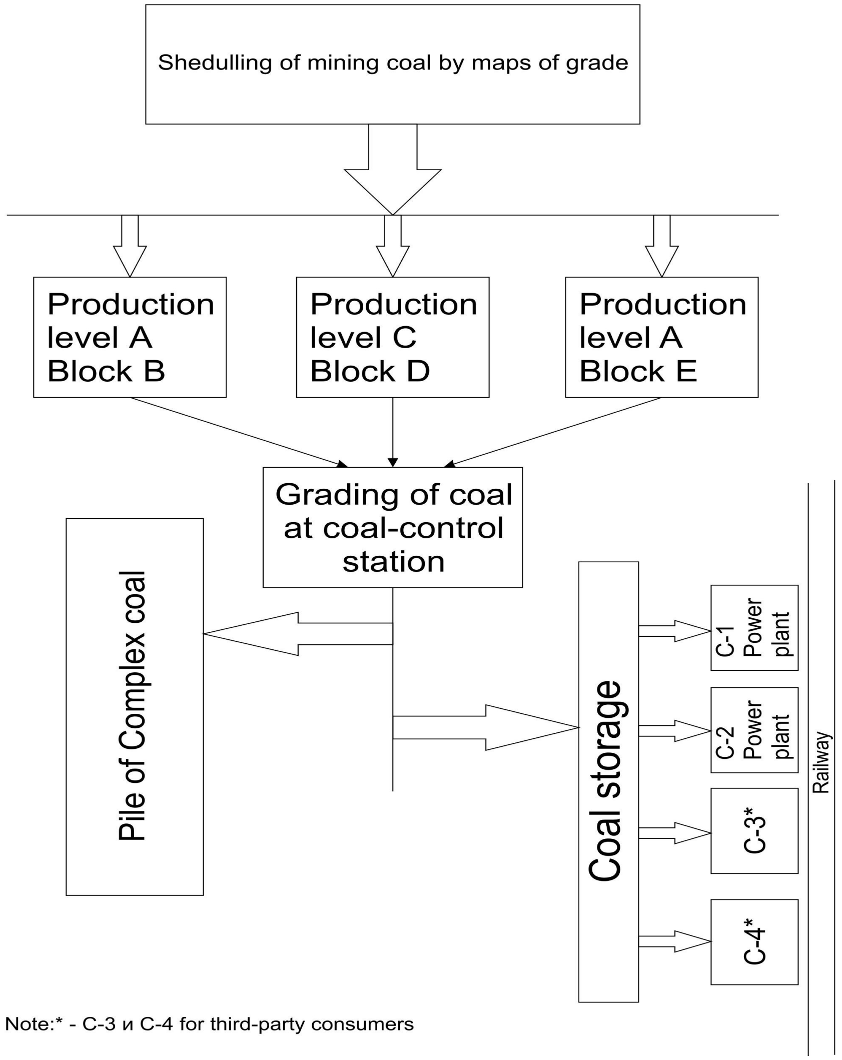


Fig.4: Scheme of mining coal with regard of its radiation property

Selective recess using the same system development that the common recess. The difference is in the separation of different grades of coal freigh traffic , changing the sequence of individual mining areas due to the formation of M for need to stabilize the quality of each variety. When this option is selected sequential mining grade sorting coal in the experimental section of coal quality control (ESCQC) and the preparation of the charge on the coal storage piles .

Such an option of different grades of coal mining in the development of acceptable fields of any capacity with different angles of incidence , provided consistency of distribution of selected varieties of coal along strike and dip. Mixing varieties produced not working face and in a coal face eliminating the isolated loading coal types in the same slaughter and significantly reduce the time of loading.

Gross coal excavation method on the lower horizons will improve the performance of loading equipment and reduce the cost of mining compared to selective extraction by 15-30%. Expediency selective extraction or gross development determined by the total cost per unit of reserves and given grade coals by radiation parameters.

The general scheme of mining coal radiation parameters using sectional level quality maps as Fig.4:

When producing *Grade complex* - coal unsuitable for thermal purposes (uranium content , % - ≥ 0,01; total specific activity , pCi / g - ≤ 46,85; estimated specific gamma activity , mR / h - ≥ 74) are stored in special dumps for their long storage.

When designing complex coal dumps must take into account the following factors: land relief, water cutting of a site, amount of precipitation, the formation of storm and flood waters , the distance transport of radioactive coal .

When forming the blade to its full scope consecutive isolation is provided of each of its parts, by covering the surface of the blade by synthetic polymer frother that prevent moisture from entering the blade and dusting the blade (Fig. 5) .

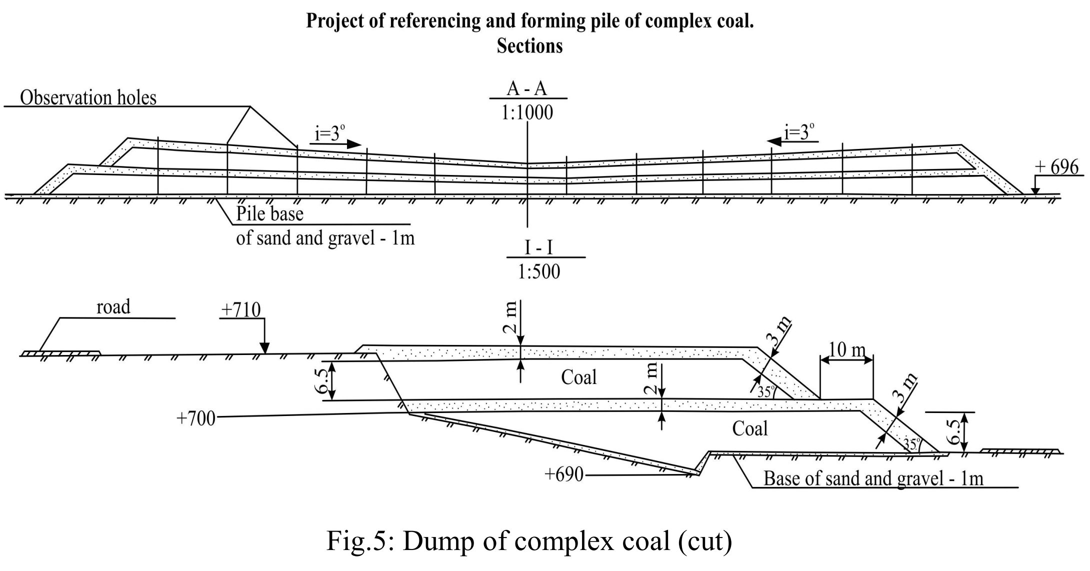


Fig.5: Dump of complex coal (cut)

A detailed study of blocks allocated to the disposal of land identified for the election recess upper part of the deposits, which allowed transferring part of coal in the energy grade and reducing losses. Application of the method of coal production planning using level mapping also allowed reducing losses during extraction of coal with a high content of radioactive elements.The total planned loss of coal deposit at 2.6 %, the actual (01.01.10 g) - 2.0 %, which characterizes the efficiency of the adopted system of field development.

3. Conclusion

Results of research on Urtuysky brown coal deposit in Transbaikalian are the solution of an actual scientific - technical problems to develop an efficient brown coal technologies and their quality control taking into account the best use of the mineral , by reducing losses and reduce the negative environmental impact of radionuclide contained in these coals.

4.References

[1] Sidorova G.P. Problems of using the coal with high radioactivity / G.P. Sidorova / / Mining Journal number 2 . - 2009 . - P.67 -69

[2] Sidorova G.P. Coals' output with a high content of natural radionuclide / G.P.Sidorova / / Industry of Kazakhstan № 1 -2012 . - S. 60-61

[3] Sidorova G..P Natural radionuclide in coal and ash in coal-fired power / D.A.Krylov , G.P.Sidorova , V.A.Ovseychuk / / Coal number 9 -2012 . - S. . 96-97

[4] Ovseychuk V.A., Sidorov G.P. The Uranium's contents to brown coal of Transbaikalian / V.A.Ovseychuk , GP Sidorova / / Monograph . - Chita: Out- of ZabGU . - 2013 . - 192 .

Advanced Technology Based on New Technological and Organizational Principles of Spatial Development of Front of Mining Operations at Open Pits

SELUKOV Alexei V.

Sub-Faculty of Open Pit Mining, T.F. Gorbachov Kuzbass State Technical University, 650000 Kemerovo, Russia

Abstract: With the development of coal deposits Siberia, the open way and justified ways of progressive technologies are researched based on the new technological and organizational principles of spatial development of the front mining operations at open pits.

Keywords: methodical positions, structural schemes of mining, quarry field.

1.Introduction

Based on a special method of mining and geometric analysis of career fields the parameters of the stages of the queues of mining and technological design of the development systems are determined and the technology of working off of deposits queues at the direction of front of mining operations are created. At the first stage,the stage of testing is performed feats not in front of mining operations stretch across layers to a certain intermediate depth development with predominantly foreign dumping of overburden rocks, and at the second stage-the stage of working off along strike layers until end depth development with a predominantly internal dumping.

2.Characteristic of the work

Major drawbacks of the longitudinal system with the development of coal have been discovered and deposits inclined steep fall are putting all overburden to external dumps. These factors in turn cause high stripping ratio and significant land capacity of coal production, loss and ore extracted coal.

In general technical policy of manufacturers of coal has a sustainable direction for the increase in internal dumping in the development and inclined steep deposits. These technologies are aimed at the elimination of the above shortcomings of such systems development.

Such schemes working off career fields are possible with cross-technologies, which include technology with the creation of the career of the first stage by P. I. Tomakov, submersible technology, layering technology and block technology [1,2].

When you cross development systems to distinguish two stages of development of mining works:

1) formation of initial career with accommodation stripping on external dumps;

2) development of the main part of the career field’s direction stripping on internal dumps.

When developing sweet steep and sloping seams mined-out space, it was considered unavailable for the placement of overburden rocks in primary and main periods of operation, which can be used effectively by changing development procedure career fields and targeted action on the management of mountain development works on the quarry and in. Guidelines when creating development systems with internal dumping mode of the current section are:

1. Available to the developed space - the current position of mining operations with the longitudinal development systems;

2. Flexible to combined connection of two major systems development, representing decisive for the open method of development of coal: a longitudinal front along reservoirs, as well as cross with front transverse to the extension of layers;

3. The development of a working zone with the selection of intermediate circuits in three-hierarchical levels: I – block; II – layer; III - area (divide by level happens to their share participate in the admissions capacity inside dump);

4.Change or no direction of front of mining operations in the dynamics of development career: transverse to the extension or strike;

increasing the concentration of mining operations and purposeful formation of the developed space with intermediate and final contours for the transition from external to partial or full internal dumping; usage of optimization of productions as for technology in general and for individual subsystems career.

5. At the present stage of research on extending the scope of application of new technologies in different mining and geological conditions of the Kuznetsk coal basin, the sum of natural and technological factors for deposits in traditional and new areas of coaloutput are considered.

The essence of transversal technologies for current mode cut with the creation of the career of the first stage consists in the following. On the one hand deposits from the current build quarry limited size up to the project depth of the so - called quarry of the first stage. The main purpose of this career - creating an initial capacity to accommodate overburden when developing remainder of deposits (fig. 1).

Moreover, the quarry of the first stage of constructing with the formation in operative boards in parts of the pit, and from the opposite side a working board career. Moving rocks provide vehicles for mines and minerals (coal) are transported to the surface in places of warehousing and processing. Since the construction of the career of the first stage is quite a long time, to minimize the amount of overburden rocks, transported to external dumps, the parameters of this career should also be the least, except depth. The main advantages of the technology considered in comparison with traditional longitudinal are: smaller land capacity of coal output due to host some of overburden rocks in the developed space; reducing the length of the transportation of overburden rocks;

The disadvantages analyzed technology should include the limitations of the front of mining operations and hard interdependence down hole and moldboard areas of the pit.

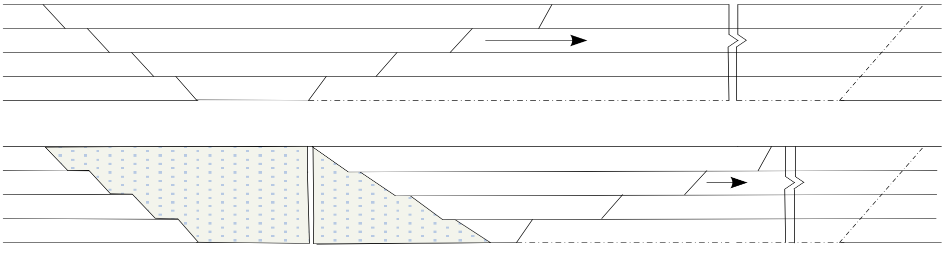


Fig. 1: Cross-technology with the creation of the career of the first stage

Earlier cross-technology with opencast first stage though and further increases the effectiveness of the open method of coal mining, in comparison with the traditional, but it has some significant drawbacks. The most significant of these is the need of focusing quarry construction of the first stage up to the boundary of depth, which lengthens the period of transition to the internal dumping and causes the violation of large areas of the earth surface external dumps. In addition, I have problems with the reconstruction career when you change the boundary of career paths.

In the Kuznetsk branch of the research institute of the open pit mining and the Kuzbass Polytechnic Institute was designed submersible technology, existence of which is as follows (fig. 2).

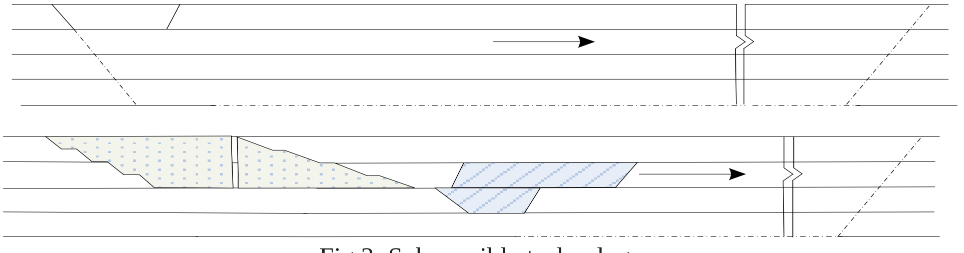


Fig.2: Submersible technology

In one side of coal deposits build on the current depth of the trench transverse to the extension of deposits at a depth equal to the height of the ledge. Rock overburdens are taken to the foreign deposits of the blade. Subsequent testing career produce when stripping the upper (first) of the ledge on the value, determined on the basis of the possibilities for accommodation of overburden of diving into the underlying aquifer. Dive mining is up to the project depth of the quarry. The working area becomes permanent, and all rock overburden moved into the internal dump. The immersion angle varies 16-18 ^{o} that determines the stability of the internal dump and time to reach the boundary of the depth of the quarry, which begins working off of deposits with full accommodation of overburden to internal dump. The use of this technology allows reducing the volume of overburden that is hosted on external dumps, and, as consequence, to reduce land capacity of the coal. In addition construction time career and terms of transition to the technology with internal dumping are reduced. When developing the lower horizon may apply non transport technology. A significant disadvantage of this technology is the conservation of a part of reserves when submerged mountain works. Possible field of application longitudinal technology is to develop a suite of coal seams inclined and steep fall of the great length of the strike.

Block technology is a further development of transversal technologies with opencast first phase (fig. 3).

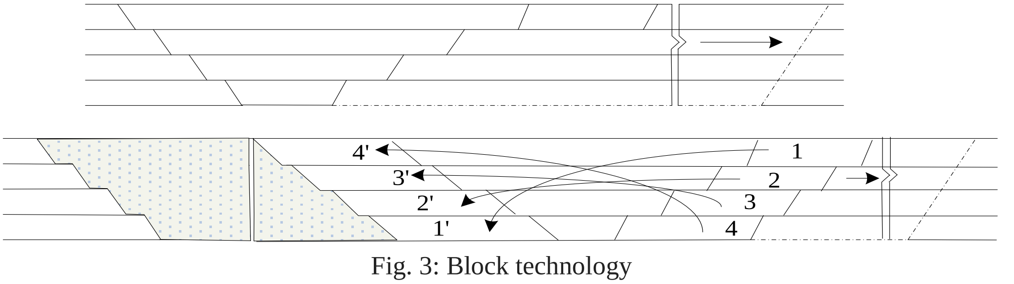


Fig. 3: Block technology

The distinctive feature of this technology is a division of the field along strike on blocks, including quarry of the first phase and blocks, working on internal dump. The mining operations begin by building a career first and its parameters are established proceeding from the possibilities for accommodation in the new mines all overburden the neighboring block. The block parameters determined on the basis of the following provisions. It is assumed that one unit is fulfilled in one year. This ensures the production capacity of the quarry. Power horizontal layer in a block is set under the terms of minimum losses and dilution during the mining of coal seams mining. The layers in the block work out consistently in descending order, starting from the top of the horizon. The seams mining work excavators type direct and inverse shovel from the hanging sides, that allows reducing the losses of coal and ore its breed. Lying of overburden rocks in the developed space perform horizontal layers, starting from the bottom of waste layer, or inclined layers under the angle of repose, as failover. The advantages of the technology are providing an enabling environment retrieves all the seams mining;, placement of overburden rocks in the developed space, high mobility of mining equipment within a layer. The disadvantages include the instability of the current stripping ratio during the year and a large volume of overburden removed to external dumps. Possible field of application technologies - development submitted suites coal seams of the complex structure and occurrence with established borders career.

The essence layer technology is the development of the deposit horizontal-governmental layers of differently movement front of works and putting all of overburden in the developed space (fig 4).

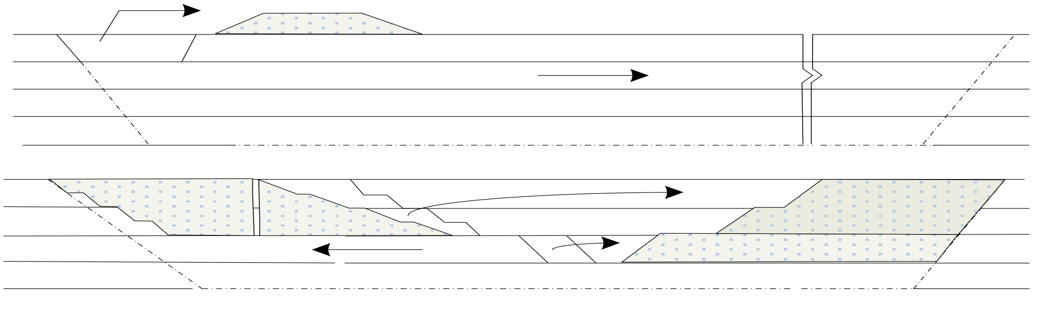


Fig.4: Layer technology

The deposit development starts with facilities in one side of career fields the transverse career digging to a depth of working layer, defined in criterion transportation work when comparing non transport and transport technology of working off of layers. Overburden rocks are placed on the surface of career fields. Possible power working layer reaches 100 meters. Width generation is established on the basis of the possibilities for accommodation of overburden when mining layer in the developed space. The lengths of the working along the bottom are equal to horizontal power mined deposits. After the construction of the cross-career excavation begin to develop the remaining part of the horizontal layer. Development layer produce one high ledge with a breakdown of its height in layers. The refinement of the layer is in descending order, starting from the top. After mastering the first layer are preparing for the development of the underlying layer. To do this in the first layer of the rock with the help of vehicles moving on the surface of the internal dump him. This creates space for the construction of cross career development for preparation for the development of underlying aquifer. While under construction production lead to removal of overburden also on the surface of the internal dump him. After the construction of the preparatory mountain developments on the second horizon produce the refinement of the second horizon layer with the placement of overburden rocks in developed-dimensional space of the same horizon. Rock overburden internal dump first horizons move into the internal dump of the same horizons on the inner surface of the blade of the underlying layer. Thus, the direction of the front of works is changed to the opposite direction, i.e. development of the lower layer is in the opposite direction. After the work of the second layer is carried out, if necessary, dive on the third horizon with observance of all technological operations specified when diving on the second horizon. In such sequence mining the horizon is achieved by equality and boundary layer stripping ratios. Feature layer technology is the presence of one of the mining layer. Waste layers are internal dumps, periodically reloaded from one position to another as working off of underplaying layers. Positive aspects of the layer technology are the absence of external dumps, reducing the land capacity of coal mining, the use of non transport technologies when developing layer, which reduces the cost of coal production the placement of overburden in the developed space results a reduction in the length of transportation and, consequently, reduces transport costs. Negative aspects are the need for repeated handling overburden internal dump, which leads to an increase of the stripping ratio. Possible field of application layer technologies are coal deposits of the great length of the strike.

3.Conclusion

According to the analysis of geological conditions, in fact, which is applied by technologies open coal mining, the possible technological solutions and requirements for perspective technologies formulated the main principles and methods of formation of structural schemes of the order of testing career fields

4.References

[1] Tsepilov I.I., Koryakin A. I., Kolesnikov V. F., Protasov S.I. Perspective technologies of open development complex-structural coal deposits // Kuzbass state technical university, 2000. –186p.

[2] Tomakov P. I., Kovalenko V.S. Rational land use in open mining // Nedra, 1984. – 213p.

Part III

Mining equipment and machinery

Modeling of Hydraulic Power Cylinder Seal Assembly Operation

BUYALICH Gennady D[1,2], **BUYALICH Konstantin G[1]**

1.Mininginstitute, T.F. Gorbachev KuzbassState Technical University,650000 Kemerovo, Russia;

2.Yurga Institute of Technology of Tomsk Technical University, 652055 Yurga, Russia

Abstract: The nature of the hydraulic power cylinder seal assembly operation with high working fluid pressure, different geometrical parameters of lip-type seal, is revealed. The method of hermetic sealing process modeling according to the simplified model using finite element method is considered.

Keywords: finite element method, modeling, hydraulic power cylinder, hermetic sealing, seal.

1.Introduction

Sealing property of hydraulic power cylinders, which include hydraulic jacks and powered support props, is determined by the size of the gap between the piston and working cylinder, as well as by the operation of lip-type seal in this gap.

This paper present comparative assessment of performance of three seals, made according to the State Standard 6678-72, State Standard 14896-84and State Standard 6969-54, which differ in shape and geometrical dimensions.

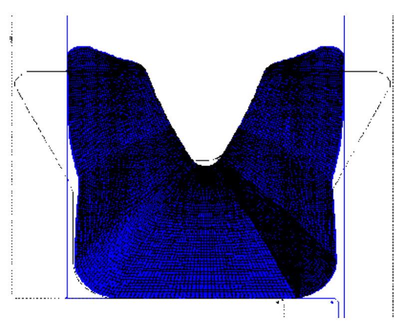
2.Work Description

The assessment of seal parameters of the sealed gap was made on parametricaxi symmetric finite element model of the seal assembly; the initial parameters being geometric dimensions of lip-type seal and lip seal groove of the piston; sealable gap, material properties, the working fluid pressure.

As the working fluid was adopted water-in-oil emulsion, sealing pressure– 50 MPa. Since the lip-type seal of hydraulic powered props lip is made of low-compressibility material, the Mooney-Rivlin model with two parameters is most suitable to describe its behavior.

According to the model the calculation was carried out in two stages: on the first stage the deformed state of lip-type seal after the cylinder assembly was simulated (Fig.1); on the second stage- from the working fluid effect in the form of distributed load on the internal sealing surfaces (Fig. 2).

a



б

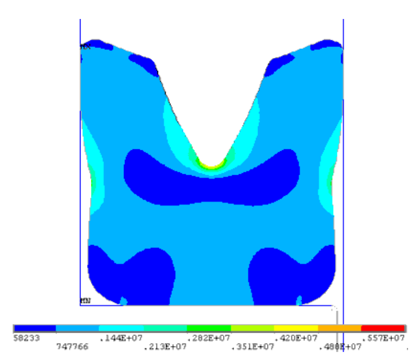
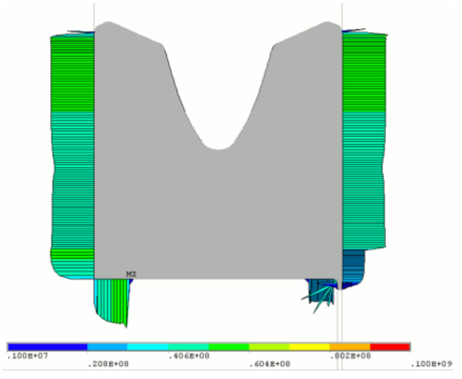


Fig. 1: Deformations (a) and load distribution according to Mises (б) in the lip-type seal on the basis of State Standard 6969-54 after assembly.

а



б

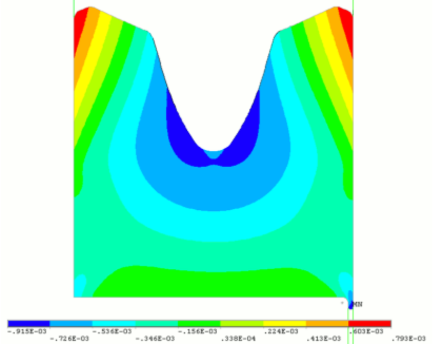


Fig. 2: Axial movement (a) и contact pressure (б) in the lip-type seal on the basis of State Standard at working fluid pressure 50 MPa.

For reliable liquid blockage the seal parts should adjoin tightly the details conjugate to them by means of preload and the working liquid pressure. The sealing parts must fit all mechanical regularities and to prevent the formation of the gap through which the fluid could leak when moving. On this basis, the following criteria for assessment of the parameters of the seal operation are proposed [1]:

- seal load factor $[n]=\dfrac{[\sigma]}{\sigma_{max}}$

where σ_{max} and $[\sigma]$ and maximum and allowable equivalent loads in the seal respectively, MPa; value of seal material pressing-out into the gapL_s, mm; relative value of seal material pressing-out into the gap, equal to the previuos value,

relative to the gap $K_з=\dfrac{L_s}{\delta}$;maximum contact pressure across the sealable surface $p_к^{max}$, MPa;

- working fluid blockage coefficient

$$К_{зп}=\frac{\overline{p}_к}{p},$$

where $\overline{p}_к$ – average contact pressure across the sealable surface, MPa;
p – working fluid pressure, MPa.
Criteria values calculated using the developed parametric model for various types of lip-type seal when the piston diameters of 220mm and gap size is of δ = 0.25mmare shown in Table1.

Table 1: Seal operation criteria values in the sealed gap

Seal type	Load factor $n_{зп}$	Pressing-out into the gap $L_з$, mm	Pressing-out, relative to the gap$K_з$	maximum contact pressure $p_к^{max}$, MPa	working fluid blockage coefficient $K_{зп}$
StateStandard 6678-72	3.1	1.06	4.2	56.7	1.13
State Standard 14896-84	4.9	0.75	3.0	48.9	0.97
State Standard 6969-54	3.9	0.63	2.5	57.1	1.14

As the table shows, the value of seal material pressing-out into the gap and Pressing-out, relative to the gapthe give the most complete assessment of seal operation in the sealed gap.

The evaluation of operation of the seal in the gap between the piston and the cylinder using the finite element method is a laborious process [2, 3]. This is due, primarily, to the nonlinearity of the outer surface of the seal and the related additional complexity of creating a regular finite element mesh, as well as to with large model formations (especially in the gap), which reduce the probability of the solution convergence.

In order to eliminate these difficulties the simplified model of lip-type seal was developed (Fig.3), which differs from the real one in the absence of "antennae". The accuracy of the results obtained on the basis of the simplified model in the gap area does not differ from the results obtained on the basis of a real model; at the height of the model being not lower then (B_up) the height of the main body of the lip-type seal. The errorin the calculationis about0.05 %.

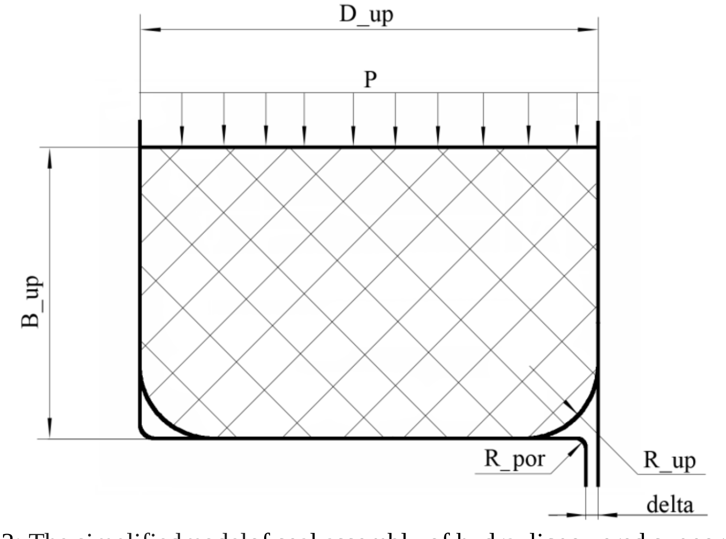


Fig. 3: The simplifiedmodelof seal assembly of hydraulicpowered support prop

The developed model allows taking into account the following parameters (Fig. 3):
•geometrical dimensions: height (B_up), width (D_up), seal rounding radius(R_up),
spherical radius of the groove edges of the piston(R_por);
• sealed gap (delta);
• properties of the seal material;
• the fluid pressure in piston cavity of the of hydraulic powered support prop (P).

3.Conclusions

On the basis of the calculations using the simplified models the basic regularities and the mode of lip-type seal behavior in the gap are found:

- pressing out into the gap and equivalent loads vary according to the linear relationship in direct proportion to the spherical radius of the groove edges of the piston(R_por), sealed gap, the fluid pressure and inversely to the spherical radius of the seal(R_up);

-the maximum equivalent loads are in the immediate vicinity to the edges of the groove of the piston(Fig. 4);

- the height increase lead to a slight decrease (within 0.001 mm per1mm of height) of the quantity of pressing out into the gap, wherein the internal load increases (0.1 MPa per1mm of height);

- the 10MPa pressure increase results in an 0.1 mm increase of the value of the pressing out into the gap and 5MPa increase of the internal load.

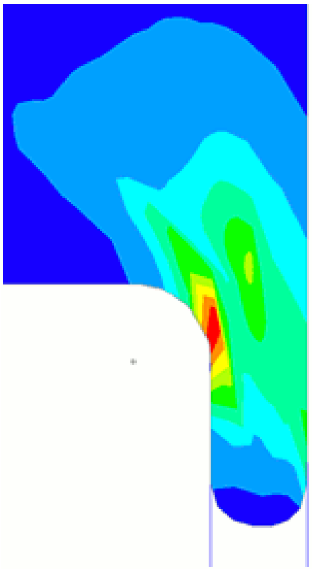


Fig. 4: Mode of deformation of the seal bear the gap

4. Reference

[1] Buyalich, K. G. Criteria of an estimation of quality of work of consolidation of hydraulic legs of powered support// Mining equipment and electromechanics. – 2009. – № 5. – 8–10 p.

[2] Aleksandrov B. A.Influence of geometrical parameters of sealing on expression size in cylinder clearance / B. A. Aleksandrov, K. G. Buyalich // Mininginformationalandanalyticalbulletin (scientificandtechnicaljournal). – 2010. – Specialedition 3: Mining engineering. – 88–92 p.

[3] Buyalich, G. D.Regular lattice of finit elements collar seals hydro desk / G. D. Buyalich, K. G. Buyalich// Mining informational and analytical bulletin (scientific and technical journal). – 2012. –Special edition 3: Mining engineering. – 119–121 p.

Formation Auger Equipment Reliability

DROZDENKO Yuri V.

Sub-Faculty of Mining Machines and Systems, T.F. Gorbachov Kuzbass State Technical University, 650000 Kemerovo,Russia

Abstract: This article contains information about determination of the parameters that affect the formation of failure auger equipment

Keywords: auger, horizontal well, communication, coefficient of concordance, χ^2 criteria

1.Introduction

Auger equipment operation can be described by multifactor model taking into account the equipment design features as well as the horizontal well construction processes (rock failure and transportation layout of the pipe casing, etc.). The choice of these parameters helps to define the rational field of auger equipment application.

2.Characteristic of the work

Based on the model proposed by prof. Posin E.Z. and prof. Linnik Y.N. [1, 2] for the description of functioning of the screw shearer executive bodies, The schematic diagram (Fig. 1) is offered for the collection and analysis of the factors affecting the auger equipment operation.

In accordance with the scheme shown in Fig. 1 the auger machine operation is characterized by a horizontal well construction process and the process of formation of failures that are in communication with groups of factors affecting the functioning of the entire technical system.

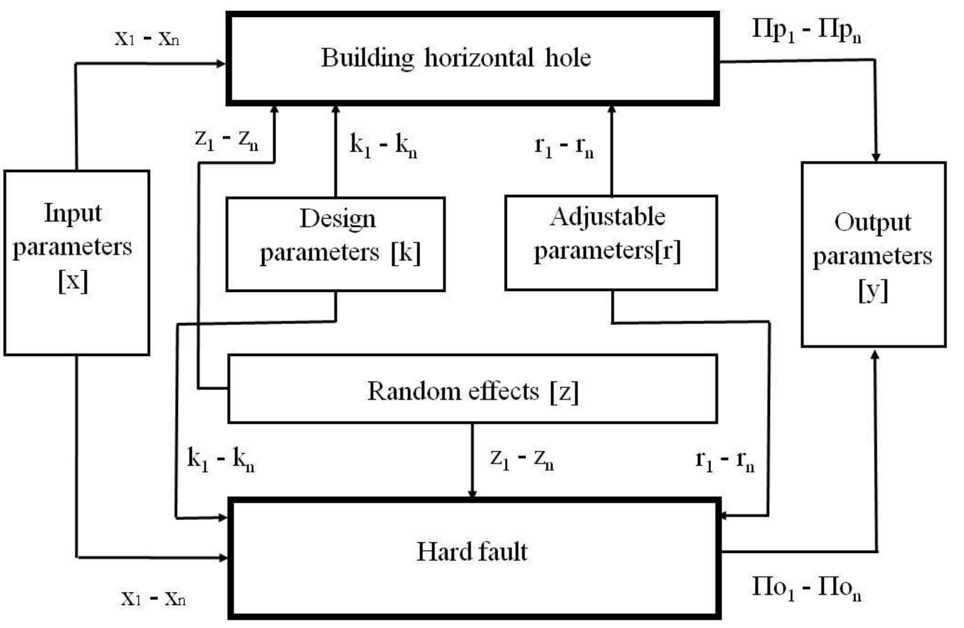


Fig. 1: Scheme of the auger machine reliability and efficiency formation

For descriptions of auger equipment **operation the following groups of factors** are used:

– input parameters (x) - characterize the properties of the soil in which it is supposed to construct a horizontal well (strength, moisture, structural heterogeneity) i.e. the parameters that can affect the formation of conditions for the occurrence of failures;

- output parameters (*y*) - characterize the actual state of the equipment and the constructed well conditions. These include the drilling process power consumption, the drilling speed, vibration level, matching a given direction, the hole diameter, the drilling flow chart, the bored mass volume;
- design parameters (*k*) - characterize the auger machine technical possibilities (geometric dimensions, the executive body design, the length and diameter of the screw section, equipment weight). This group of parameters is formed while designing the auger machine and is not changed during operation;
- adjustable parameters [*r*] - this group of parameters can to be changed during operation (rotational velocity, the pressure in the hydraulic system, power consumption, speed-power characteristics of the feed) for obtaining the optimal output parameters;
- random effects [z] - this group of parameters is random and cannot be the subject to any forecast. This primarily relates to the mass heterogeneity, in which is the well is constructed. Anthropogenic pollutions can significantly slow down the drilling process or stop it at all.

It also relates to consumables (fingers, drilling locks). The presence of defects associated with the quality of material and manufacturing, may cause failures leading to the auger equipment emergency shutdowns.

In order to quantify the auger equipment performance parameters it is possible to use a large number of indicators. According to [3], all the indicators are divided into the following groups:

– by the assessment completeness;
– by the significance;
– by the analysis field;
– by the expression method.

Each group of parameters describing the auger machine operation contains a significant number of indicators, the analysis of which will take a long time. Therefore it is necessary to single out such group of indicators that would most fully characterize the process of the horizontal well construction. To determine the most significant indicators the method of rank correlation may applied. It involves the choice of indicators and their ranking, ranking processing and determination of the most significant indicators[3], obtaining a generalized opinion based on multiple judgments of experts.

Processing method is universal and includes four main stages:

1) converting the results of expert assessments in a form suitable and convenient for processing (matrix of ranks);

2) conformity analysis of the expert opinions;

3) determination of highly conformed subgroups characterized by the proximity of views of experts included in those subgroups;

4) generalized opinion synthesis, consisting in combining of particular assesses into the overall total indicator or group of indicators.

On the base of on the survey of the experts the rank matrix for each group of factors describing the machine auger operation (Table 1-5) were composed, and each indicator has been assigned its own assessment.

Table 1: Rank matrix of input parameters

Specialists		1	2	3	4	5	6	7	8	9	10
Indicators	P1-Strength	7	7	4	8	2	5	3	1	7	6
	P2- Hardness	2	4	1	4	7	3	7	4	5	4
	P3- Humidity	3	2	7	1	1	2	6	3	1	3
	P4- Abrasivity	1	3	3	2	8	1	4	5	4	1
	P5- Fracturing	4	5	6	3	4	6	2	6	2	5
	P6- Foliation	8	1	2	5	3	4	1	2	3	7
	P7- Rock drillability grade	6	6	5	6	5	8	5	7	8	2
	P8-Structural inhomogeneity	5	8	8	7	6	7	8	8	6	8

Table 2: Rank matrix of output parameters

Specialists		1	2	3	4	5	6	7	8	9	10
Indicators	P1-Borehole axis accordance with the given direction	5	1	1	4	1	1	2	3	1	5
	P2-Energy intensity of well construction	3	7	6	7	7	6	7	6	6	7
	P3-Well diameter	4	2	2	2	2	3	1	4	4	4
	P4-Actual velocity of drilling	1	4	3	5	4	4	5	5	3	3
	P5-Vibration level	7	5	7	6	6	5	6	7	7	6
	P6-The bored mass volume	2	3	4	1	3	2	3	2	2	1
	P7-The drilling flow chart	6	6	1	3	5	7	4	1	5	2

Table 3 : Rank matrix of design parameters

Specialists		1	2	3	4	5	6	7	8	9	10
Indicators	P1-Drive capacity	8	9	8	9	8	7	9	9	8	9
	P2-Pressure in the hydraulic system	3	4	4	2	2	3	5	4	6	4
	P3-Geometric dimensions	7	7	6	8	1	2	2	3	1	2
	P4-Quantity of feed cylinders	4	5	3	5	7	5	4	5	2	1
	P5-Kind of consumed energy	9	8	9	6	9	4	8	6	4	5
	P6-Executive body design	6	6	7	7	6	8	7	8	9	8
	P7-Screw section overall dimensions	1	3	2	4	4	6	6	1	5	6
	P8-Feed cylinder stroke length	5	2	1	3	3	9	1	2	7	7
	P9-Equipment mass	2	1	5	1	5	1	3	7	3	3

Table 4: Rank matrix of adjustable parameters

Specialists		1	2	3	4	5	6	7	8	9	10
Indicators	P1-Screw section rotational velocity	2	1	2	3	2	1	2	3	1	2
	P2-Possibility to change the pressure in the hydraulic system	5	5	4	5	5	5	4	5	5	4
	P3- Quantity of operating feed cylinder	3	2	1	2	3	2	1	2	2	1
	P4-Power consumption	6	6	6	4	6	6	6	4	6	6
	P5-Feed velocity	1	3	3	1	1	3	3	1	3	3
	P6-Feeding pressure	4	4	5	6	4	4	5	6	4	5

Table 5: Rank matrix of random parameters

Specialists		1	2	3	4	5	6	7	8	9	10
Indicators	P1-Mass heterogeneity	2	3	2	1	3	1	3	3	3	3
	P2-Presence of anthropogenic refuse	6	6	5	5	6	4	7	5	5	6
	P3-Connector quality	3	4	1	4	4	3	2	2	1	4
	P4-Presence of electricity source	5	5	4	3	5	2	5	4	2	2
	P5-Unaccounted communications	7	7	6	7	7	5	6	7	7	7
	P6-Hydro-geological conditions	4	1	3	3	1	6	1	1	4	1
	P7-Weather conditions	1	2	7	6	2	7	4	6	2	5

The coefficient of concordance characterizing the conformity of rankings carried out by experts is calculated for each matrix. The coefficient of concordance is the common rank correlation coefficient for the group consisting of *n* experts. Value range is 0 <*W* < 1. When all the experts give the same estimates, *W*=0. In the case of a complete lack of conformity the assessments are accidental and *W*=0. In other cases – the more W is, the higher is the conformity of expert rankings.

$$W = \frac{12S}{m^2(n^3-n) - m\sum_{j=1}^{n} T_j}, \qquad (1)$$

$$T_j = \frac{1}{12}\sum_{1}^{k}(t_j^2 - t_j);$$

k – the number of groups of the same ranks in each ranking (since, there are no indications of the same rank in the estimates of experts T_j=0);

$$S = \sum_{i=1}^{n} d_i^2$$

$d_i = \sum_{j=1}^{n} q_{ji} - 0{,}5\; n(m+1)$ - centralized rank value of each indicator;

$\sum_{j=1}^{n} q_{ji}$ - sum of the ranks for each indicator *n* – number of specialists;*m* – number of indicators.

The results of calculations of the coefficients of concordance for each matrix of the groups of parameters are presented in Table 6.

Table 6: Values of the coefficient of concordance

Groups of parameters	Value of the coefficient of concordance, *W*
1. Input parameters	0,43
2. Output parameters	0,45
3. Design parameters	0,43
4. Adjustable parameters	0,78
5. Random parameters	0,41

The value of the coefficient of concordance *W*=0 means the inconformity of expert opinions; if *W*=0.40–0.50, the quality of assessment is considered satisfactory; when *W*>0,70 the quality of assessment is considered high.

To determine the significance of concordance criterion is possible with the use of χ^2criterion (Pearson criterion). The value of this criterion depends on the number of degrees of freedom (1.2) and confidence probability (confidence probability *P*=0.90 was adopted for calculations).

$$\nu = m - 1 \qquad (2)$$

$$\chi^2 = \frac{12S}{n \times m(m+1) - \frac{1}{m-1}\sum_{j=1}^{n} T_j} \qquad (3)$$

The results of calculation of χ^2 criteria values are listed in Table 7.

Table 7: χ^2 criteria values

Groups of parameters	χ^2	$\chi_{табл}^2$
Input parameters	23,26	2,83
Output parameters	38,6	2,20
Design parameters	39,20	3,49
Adjustable parameters	34,20	1,61
Random parameters	35,16	2,20

When comparing the obtained χ^2 criteria values with the table critical values it possible to see that the calculated values are much greater than the table ones. This suggests that there is full conformity of experts at ranking of the factors affecting the auger equipment operation [4, 5].

To determine the most significant factors it is necessary to determine the significance level for each group of parameters - this can be done using the method of proportional relations. The number of significant figures (h) is equal to the number of summands of proportional relationship numerator.

$$\frac{\sum_{i=1}^{h} V_i}{\sum_{k=h+1}^{n} V_k} \geq 1$$

where Vi = Kn – Ki; Vk = Kn – Kk – wights of i and k indicators;Kn , Ki , Kk - sums of ranks of n, k and i indicators.

The ranking histograms are created to determine the number of significant figures.

After determining the number of significant factors, the level of significance is determined by the following expressions:

$$K_{зн} = \begin{cases} K_h & \Delta\{K\}_1 > \Delta\{K\}_2 \\ K_i + \dfrac{K_n h}{n} & \Delta\{K\}_1 < \Delta\{K\}_2 \end{cases} \quad (5)$$

where $\Delta\{K\}_1 = \dfrac{K_h - K_i}{h}$ - average value of distribution amplitude of rank sums; $\Delta\{K\}_2 = \dfrac{K_n - K_{h+1}}{n-h}$ - average value of distribution amplitude of insignificant indicators.

The results of $K_{зн}$ calculations are presented in Table 8.

Table 8： The results of the significance level calculation

Groups of parameters	Number of significant factors ***h***	**Δ{*K*}$_1$**	**Δ{*K*}$_2$**	***K*$_{зн}$**
Input parameters	2	2.5	6.50	46,75
Output parameters	2	5.0	7.75	40,07
Design parameters	3	7.3	4.15	48,3
Adjustable parameters	2	1.5	8.5	37.6
Random parameters	2	9.5	6.2	42,8

3.Conclusion

Comparing the obtained $K_{зн}$ values with the histogram values, we choose those factors the $K_{зн}$ values of which are above the designed values, they are the most important indicators.

4. References

[1] Dokookin A.V., Frolov F.G., Posin E.Z. Choice Parameters of Winning Machine // M.: Nauka, 1976.

[2] Linnik Y.N. Basis of Calculation of Reliability and Efficiency of the Winning Machine in Various Operating Conditions // M.: A.A. Skochinskiy Institute of Mining, 1991.

[3] Kvagenidze V.S. Diagnostics, Maintenance and Repair of the Career Mining Equipment at Low Temperatures // Kemerovo: KuzSTU, 2003/

[4] Karasev A.I. Theory of Probability and Mathematical Sstatistics // M.: Statistika, 1970.

[5] Rygev P.A. Mathematical Sstatistics in Mining // M.: Vishaya Shkola, 1973.

Stress-Deformed State Knots Fastening of a Disk Tool on the Crowns of Roadheaders

KHORESHOK ALEKSEY[1], MAMETYEV LEONID[1], BORISOV ANDREY[1], VOROBIEV ALEKSEY[2]

1.Department of Mining Machines and Complexes/Mining Institute, Kuzstu Named T.F. Gorbachev Kemerovo, Vesennyaya, 28, 650000, Russia
2.Department of Mining Equipment, Yurga Institute of Technology, TPU Affiliate Yurga, Leningradskaya, 26, 652055, Russia

Abstract: Presents innovative technical solutions, research results and recommendations based on mine testing and modeling of stress-deformed state knots of fastening disk tool for different variants of the structural design, including many-sided prisms at destruction faces crowns roadheaders selective action.

Keywords: Roadheader, effector, crown, triangular prism, knot fastening, disk tool, destruction, crushing, loading, stress state, finite element method.

1.Introduction

In the leading mining countries the main means of mechanization for mining are Roadheaders. Improvement of effectors of the boom-type roadheaders and heading-mining combines by rational combination and the placement of cutter and disk tool for the implementation of the principle of destruction of coal and hard rock large-sized is an actual problem. This disk tool implements the possibility of the reverse motion of the working bodies of the model of mining machines, including crowns roadheaders, increasing the scope of their application to the destruction of the heterogeneous, hard and abrasive rocks [1].

2.Experience of application of disk tool

Disk usage of tools for crowns of roadheaders selective action is a perspective direction in development of efficient rock cutting tools for mechanical destruction method of coal and strong abrasive rocks with the hardness coefficient $f \leq 10$.

It is confirmed by researches at the chair of mining machines and complexes KuzSTU named T.F. Gorbachev. Tested four types of crowns roadheaders selective action, which are distinguished by the number of cutters and disk tools, step-install them, screw-line set of working tool, the design of the knots fastening disk, cutting part of the crown and the presence of loading blades [2].

The method and conditions of mine testing implemented when working on ore and coal veins with hard inclusions and layers with compressive resistance (σ from 87 to 112 MPa).

The tests were performed in two stages. The first stage included research of the roadheader, equipped with a serial crown with cutters, the second stage included the experimental crowns, equipped disk tools. In the process of comparative research was determined by the force and energy performance of the roadheaders and the specific consumption of the working tools. General view, the scheme of recruitment and placement of rock cutting tools for experimental samples of the working bodies in the form of a longitudinal axis of the crowns of times-personal design is presented in fig. 1–4. Crowns are composed of the following structural elements: 1 – blank crown: 2 – disk tool; 3 – cutter; 4 – starting borer; 5 – cutting disc; 6 – loading the blade.

In fig. 1,a presents design, in fig. 1,b shows the assembly elements of the experimental model of the crown, on fig. 1,c depicted crown on the boom roadheader, as in fig. 1,d shows the knots fastening of the disk tools.

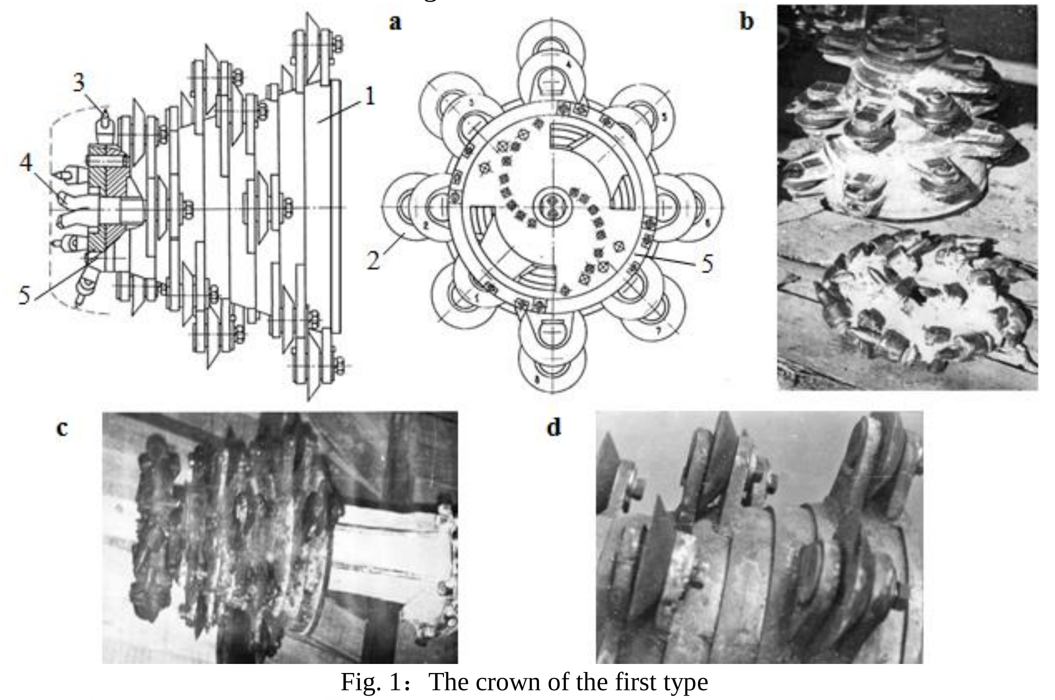


Fig. 1: The crown of the first type

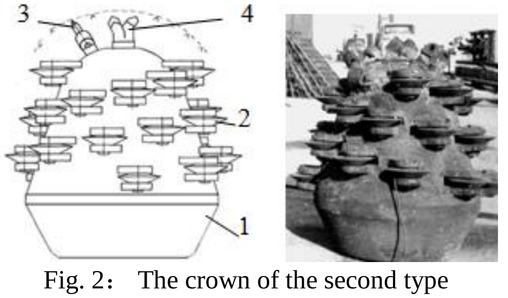


Fig. 2: The crown of the second type

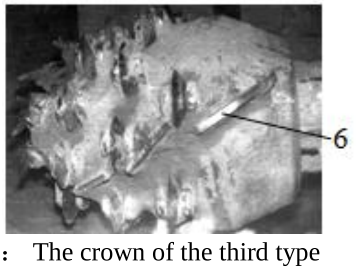


Fig. 3: The crown of the third type

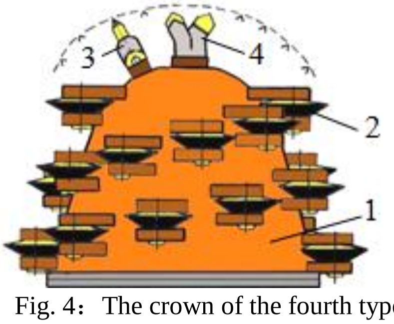


Fig. 4: The crown of the fourth type


Fig. 5: Disc tool

For the study was made of disk tool of the same diameter D = 160 mm, but three designs (fig. 5). Disks first performance had at the angle of taper $\varphi = \varphi_1 + \varphi_2 = 30+5 = 35°$. Disks second performance $\varphi = \varphi_1 + \varphi_2 = 25+5 = 30°$. Disks third of execution had the edge with curved teeth profile with the angle of taper $\varphi = \varphi_1+\varphi_2 = 30+5 = 35°$.

On the crown of the first type (fig. 1) used the knot fastening bolted connection (fig. 6,a), and the other three crowns (fig. 2–4) was used “quick-dismountable” knot fastening (Fig. 6,b) [3].

Double-seat knot fastening (fig. 6,a) consists of two brackets 1 and 8, in which the axis 2 flange fixed conical disk tool 3 with remote rings 4. From the axial displacement of the axis 2 fixed washer 5, bolt 6 and spring washer and from turning axis 2 fixed planck 7.

In fig. 6,b shows double-seat knot fastening consisting of two brackets 1 and 8, in which the axis 2 is fixed biconical disk tool 3 with remote rings 4. For fixation of axis 2 of the inside of the right-bracket 8 is a slot 5 with locking ring 6 and rubber gasket 7, and in the left bracket 1 is executed a groove 9.

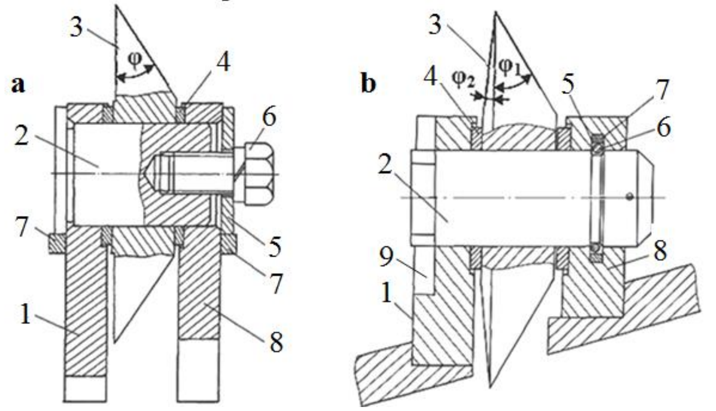


Fig. 6：The design of the knots fastening disk tools

During the tests revealed the complexity of direct cutting boom of the crown of the first type (fig. 1) due to high axial workloads. Design of the crown of the second type
(fig. 2) showed high efficiency, especially in the mode of cutting. At the crown of the third type (fig. 3) with loading blades was marked by the accumulation of sand and clay rocks and sharp deterioration of loading capacity, when working in water bearing layers. Design of the crown of the fourth type (fig. 4) unified on the basis of the second type (fig. 2), that is, truncated on the latter two knot fastening disk tools in each line cutting. There were received satisfactory energy and extended the field of application of the roadheader on hard rocks.

To obtain comparative data, characterizing the degree of loading of transmission and electric motor of the crown, were measured power consumption of the electric motor, the feeding speed of the crown and the pressure in the hydraulic system roadheader for indirect assessment of efforts arising from the work tool.

Currently one of the effective methods of research of stress-deformed state of knots fastenings disk tool and forming loads on a disk tool in the destruction of coal faces is the method of finite elements.

At the first stage of research on finite element modelling was carried on a double-seat knots fastenings (fig. 6,b) with the disk tools of various design (fig. 7) to establish the parameters of the stress state at the account of the characteristics of the destroyed mountain range $\sigma = 50 \div 140$ МПа [3]. Considered four variants of constructions disk tool diameter D = 160 mm (three biconical with angle of taper: $\varphi = \varphi_1+\varphi_2 = 25°+5° = 30°$; $20°+10° = 30°$; $15°+15° = 30°$ and one conical $\varphi = 30°$).

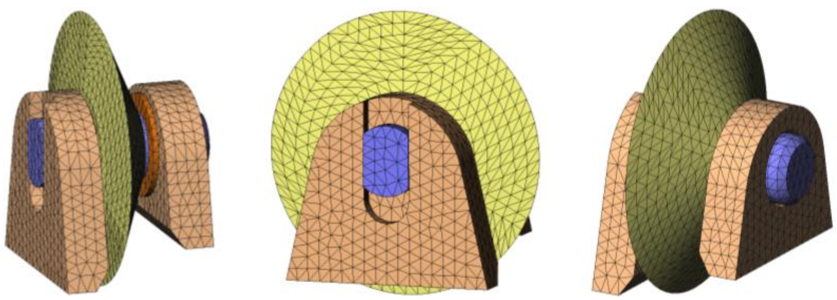


Fig. 7：Finite element model of a double-seats knot fastening disk tool

The calculation was made in the system SolidWorks Simulation. When creating a mesh was used parabolic finite elements in the form of tetrahedra. The size of finite elements was chosen so that a further increase in the density of the mesh not have a material impact on the results of the calculations. Material of details – 35HGSA. When describing the conditions of interaction between details in an assembly used the contact condition "No penetration". To fasten knot in the calculation were applied boundary conditions "Fixed", is attached to the bottom edge of the supports.

By calculation [3] were determined efforts cutting P_z, implementation P_y and side efforts P_x on a disk tools with regard to design, operating parameters and characteristics of destructive massif σ. Estimated efforts of loading P_z, P_y, P_x were attached to the finite element models (fig. 7) disk tools in the double-seat knots fastening, in which produced a picture of the stress-deformed state for biconical and conical disk tools (fig. 8) [3, 4].

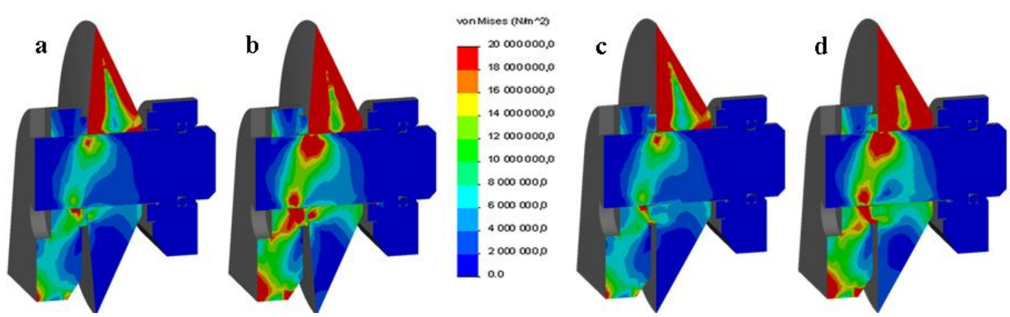


Fig. 8. The distribution of equivalent stresses on the criterion of Mises in the double-seat knots fastening: - for biconical disk tool ($\varphi = 25^\circ + 5^\circ = 30^\circ$) for conditions: a – σ = 70 MPa; b – σ = 120 MPa; - for conical disk tool ($\varphi = 30^\circ$) for conditions: c – σ = 70 MPa; d – σ = 120 MPa

In addition, gumming radially split between bearings spaces knot fastening the disk tool products destruction and their adhesion to the working surface of the blank crown and blades of decrease of efficiency of processes of destruction and loading of the rock mass on the loading table roadheader.

In practice underground coal mining known that roadheaders provide the driving of mine workings with given sizes of cross section (S) and width ($B_{в}$). Each roadheader (table 1) has the width of the loading table ($B_{п.с}$), a smaller width entry ($B_{в}$), which complicates the process of loading a bing of rock mass near the edges of mine [4].

The difference (Δ) between the width entry $B_{в}$ and width loading table $B_{п.с}$, characterized the presence of two corridors near the edges of mine not covered with the loading table.

Table 1：Mapping the width of the loading table with a width of mine

Roadheaders	Maximum cross-section entry S, $м^2$	Maximum width entry $B_в$, м	Width loading table $B_{п.с}$, м	The difference $\Delta = B_в – B_п$
1GPKS	17,0	4,7	3,02	1,68
KP21	28,0	6,5	3,4	3,1
SM-130K	19,0	5,005	3,0	2,005
П-110	30,0	6,7	3,8	2,9

In fig. 9 shows the circuit of formation tests strips from the bing not shipped products of destruction of a typical effectors roadheaders selective action: a – when operating radial crowns; b – in the operation axial crowns. The process of loading near the edges of mine is characterized by the following parameters: $B_{и.о.}$ – working width of the effector; $B_{лн.ш.}$ – width not shipped bing products of destruction at the left side; $B_{пн.ш.}$ – width not shipped bing products of destruction at the right side; $B_в$ – width project entry; $B_{п.с.}$ – width of the loading table, describing the width of the area of the front loading [5].

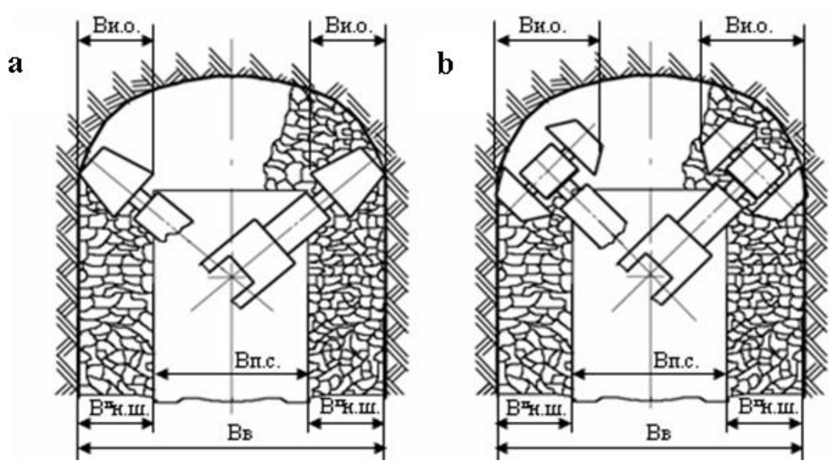


Fig. 9：The scheme of formation of the front loading at driving

One of the most important requirements to the construction of effectors of roadheaders selective action is the expansion of the front loading of near the edges of mine on the loading table. The application of the crowns of domestic and foreign production solid screw spirals improves the process of loading only one of the sides of mine working, but worsens it from the opposite side. However, even screw radial crowns do not cover the entire width of edge band at the loading table, forming spillages and demanding maneuvering and loading of back-circular races roadheader. This increases the duration of the operating cycles and reduce the rate of work.

It is therefore of particular interest to develop technical solutions in the reverse mode of operation radial crowns selective action to combine the processes of destruction of rock mass on coal face, crush oversized, and loading on the table of the roadheader in any edges of mine working [6]. The basic foundation of such technical solutions are knots console fastening disk tool on brackets in the form of triangular prisms [7–9].

Realization of these technical solutions will allow to expand the application domain swept roadheaders selective action on carrying out of mountain developments in the faces with heterogeneous-structure of rocks in a wide range of operating conditions.

For the last 3-5 years, the department of mining machines and complexes KUZSTU named T.F. Gorbachev together with the department of mining equipment Yurga Institute of Technology, TPU conducted research work on the study of stress-deformed state of various designs knots console fastening the disk tool on brackets in the form of triangular prisms to reverse radial crowns (fig. 10) [10].

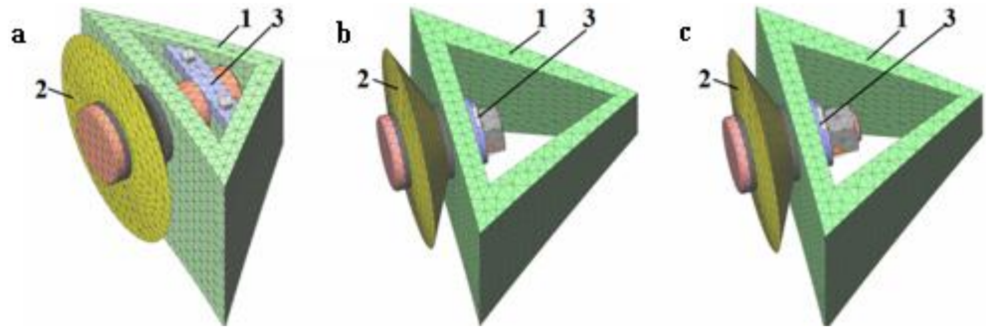


Fig. 10：Finite element model of three variants of constructions fixing disk tool to trihedral prisms: a – the first with strap-lock; b – the second with the mounting screw; c – third with nut; 1 – triangular prism; 2 – disk tool; 3 – knot fastening

In each design was used as a biconical and conical disc tools. Strategy in the construction of finite-element models and calculation of efforts loading P_z, P_v, P_x was similar to double-seat knot fastening of the disk tool. As an example in fig. 11[4] presents the distribution of equivalent stresses the Mises criterion for three variants of knot fastening disk tool diameter D = 160 mm in trihedral prisms.

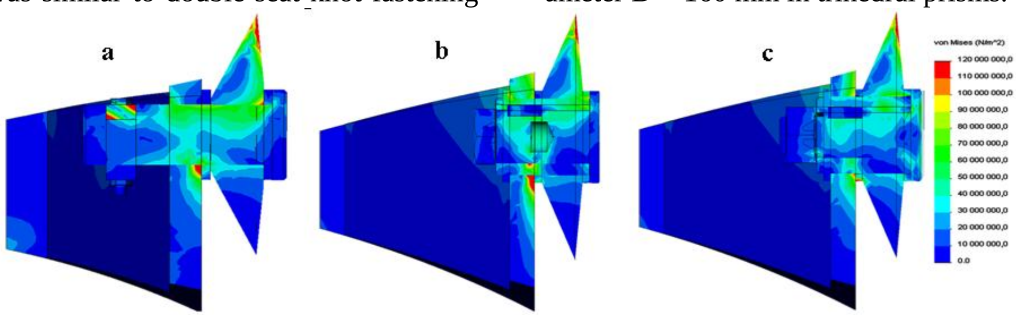


Fig. 11. The distribution of equivalent stresses in the Mises criterion for three variants of knots fastening disk tools with an angle of taper φ = 25°+5° = 30° in trihedral prisms taking into account the characteristics of the destructible array σ = 70 MPa: a – the first bar-lock; b – the second with the mounting screw; c – the third with nut

The technical solutions console knots fastening the disk tool on the trihedral prisms, taking into account the results of modeling of stress-deformed state in the destruction of coal faces, will recommend them for equipment of the working bodies roadheader, shearers and drilling combines of domestic and foreign production.

3.Conclusion

It is established that the equivalent stress on the criterion of Mises in all versions knots fastening disk tool radial crowns roadheaders significantly lower yield stress for steels 35HGSA (σ_T = 490 MPa). With the transition from the asymmetry for symmetry biconical disk tools can be traced reduction zone settings equivalent stresses in knots fastening with the general increase of the maximum stresses with increasing strength of rocks in a wide range σ = 50–120 MPa.

It is revealed that, disk tools conical (φ = 30°) and biconical performances (φ = 25°+5° = 30°) implement the process of destruction of large areas of maximum equivalent stress and displacement than options biconical execution (φ = 20°+10° = 30° и φ = 15°+15° = 30°), and the minimum dimensions of zones of equivalent stresses and displacements marked for biconical execution (φ = 15°+15° = 30°).

Decreased size of the zones of maximum equivalent stress and displacement on downhole the verge of a triangular prism, turned to face the third option of the knot fastening disk tool, compared with the second option, which is characterized by a higher rigidity fixing nut.

The requirements to the structures of effectors with two reverse francis crowns, the basis for the creation of which is proposed to use the complex of technical decisions on knot fastening disk tools in trihedral prisms and the results of modeling the stress-deformed state to expand the field of application roadheaders selective action of domestic and foreign production.

4.References

[1] About the state and prospects of development of means of mechanization of mining and tunneling works in the conditions of the Kuznetsk coal basin / A. A. Khoreshok, V.V. Kuznetsov, A. Yu. Borisov // Mining equipment : landings, transportation and processing of minerals: the catalogue, 2008. – SPb. : Slavutich. – P. 12–16.

[2] Perspectives of applying of the disk cutter for bits of heading machines / A. A. Khoreshok, L.E. Mametyev, V.V. Kuznetsov, A. Yu. Borisov // The bulletin of KuzSTU. – Kemerovo, 2010. – № 1. – P. 52–54.

[3] Distribution of pressure in knots of fastening of the disk tool on heads roadheaders / A. A. Khoreshok, L.E. Mametyev, V.V. Kuznetsov, A. Yu. Borisov, A.V. Vorobiev // The bulletin of KuzSTU. – Kemerovo, 2012. – № 6. – P. 34–40.

[4] Designing of reversive heads for boom-type roadheaders with the disk tool on replaceable trihedral prisms / A.A. Khoreshok, L.E. Mametyev, A.Yu. Borisov, S.G. Muhortikov, A.V. Vorobiev // Mining equipment and electromechanics. – 2013. – № 9. – С. 40–44.

[5] The effector of road heading machine for overlapping processes of destruction face with crush of lumps and loadings of mined rock / V.I. Nesterov, L.E. Mametyev, A.A. Khoreshok, A.Yu. Borisov // The bulletin of KuzSTU. – Kemerovo, 2012. – № 3. – P. 112–117.

[6] Patent 2455486 RU. Tunnelling machine actuator / L.E. Mametyev, A.A. Khoreshok, A.Yu. Borisov, V.V. Kuznetsov, S.G. Muhortikov; patent owner KUZSTU. –№ 2010141881/03 ; declared 12.10.2010 ; published 10.07.2012, bulletin № 19. – 14 p.

[7] Patent 128898 RU. The knot fastening of the disk tool in triangular prism / L.E. Mametyev, A.A. Khoreshok, A.Yu. Borisov, S.G. Muhortikov, A.V. Vorobiev; patent owner KUZSTU. – № 2013100882/03 ; declared 09.01.2013 ; published 10.06.2013, bulletin № 16. – 2 p.

[8] Patent 134586 RU. Device for protection of internal space of a triangular prism from the products of destruction / L.E. Mametyev, A.A. Khoreshok, A.Yu. Borisov, A.M. Tshehin; patent owner KUZSTU. – № 2013127350/03; declared 14.06.2013; published 20.11.2013, bulletin № 32. – 2 p.

[9] Patent 141339 RU. The knot fastening of the disk tool on the working body of mining combine / L.E. Mametyev, A.Yu. Borisov; patent owner KUZSTU. – № 2014103560/03; declared 03.02.2014; published 27.05.2014, bulletin № 15. – 3 p.

[10] Improvement of designs of fastening knots of the disk tool on radial heads of roadheaders / L.E. Mametyev, A.A. Khoreshok, A.Yu. Borisov, A.V. Vorobiev // The bulletin of KuzSTU. – Kemerovo, 2014. – № 1. – P. 3–5.

Preventive Maintenance of Mining Equipment Based on Identification of Its Actual Technical State

Vladimir Kovalev, Boris Gerike, Aleksey Khoreshok, Pavel Gerike

T.f. Gorbachev Kuzbass State Technical University, Mining Institute, 650099, Kemerovo, Russia

Abstract: The article treats new approach to technical maintenance of open pit excavators based on identification of technical state by functional diagnostics methods. It shows that applied diagnostics methods practically give full picture of actual state of diagnosable equipment which allows to estimate residual work capacity resource.

Key words: open pit excavators, technical state, diagnostics, residual work capacity resource.

1.Introduction

Nowadays system of scheduled preventive maintenance of equipment is used in open pits of Kuzbass. The main task of the system is to provide work capacity of equipment during preset time and at minimum labour and material asset costs. The present system is based on planned replacement of worn-out parts. The time for parts replacement is calculated on the bases of forecasted parts wear rate. Progressive (wear-out) failures are the most typical failures for rotating equipment.

Maintenance frequency is fixed according to lifetime of group of parts. At the same time, lifetime of each part is close to average lifetime and it can be used to fix the frequency of maintenance of mechanism and machine. The possibility of grouping of working lives of parts according to average values for each group is the main requirement of maintainability of mechanism and machine. In all cases it's important for frequency of repairs, i.e. working lives of parts to be divisible to each other. Frequency of repairs of excavators is set in such a way that parts with emergency phase of wear (at frequency bigger than the lifetime of a group of parts) don't work in mechanisms and parts whose work capacity resource is not completely used (at frequency smaller than average lifetime of group of parts) are not replaced during repair.

There is no theoretically justified decision of given problems in the system of technical maintenance of excavators yet. This creates great choice of recommendations on repair cycle structure formation and setting of different inter repair time for the same machine. For example, according to manual No. 2341IE NKMZ(№2341ИЭ НКМЗ) for excavator ESH 10/70A (ЭШ 10/70А)it is recommended to carry out technical maintenance No. 1-5 with frequency: shift, decade, month, three and six monthes.Leningrad office of the State Institute of design of mine construction of coal industry (Ленгипрошахт) recommends to carry out repair inspection, maintenance and capital repairs according to frequency 500, 5000, 12000, 24000 machine-hours. Research Institute of Open-Cast Mining (НИИОГР) suggests plan repair works depending on volumes of processed run of mine taking into account a number of coefficients considering operation conditions of excavators.

Each normative document establishes rigidly regulated amounts of work during excavator repairs regardless of its technical condition; volumes of repair work increase as repair complexity. For example, at average repair it is necessary to carry out extra works of annual and monthly repairs. Irrespective of operating conditions of parts and assembly units repairs are planned according to one of the criteria - calendar (or machine) operating time or processed run of mine.
All this leads to:

- under exploitation of resource of separate parts, units and assembly units of excavators;
- performance of increased volume of dismantling and assembling works which don't correspond to technical condition of mechanisms and devices, and at the same time, to increase the probability of fast wear of parts caused by wear-in because of frequent dismantling and assembling;
- considerable time of repair ofexcavators (20-25% of calendar time fund).

The system of scheduled preventive maintenance in many cases can be used as basis for the service of simple cars and mechanisms, but its application for the main equipment without reserve is inexpedient. Therefore further development of maintenance system should be provided: the establishment of differentiated criteria of assessment of parts resource, assembly units and mechanisms of excavators considering specific conditions of their work; purpose of concrete terms and amounts of work at repairs of excavators depending on actual technical condition of its parts, assembly units and mechanisms.

2.Work description

The main idea of the equipment maintenance repair system according to actual technical condition consists in elimination of equipment failures at the stage of their origin [1]. It becomes possible with the methods of identification of equipment technical condition according to its operational characteristics, allowing reveal available and developing fault for rational planning of optimal terms of repair work performance.

Technical base of equipment maintenance and repair according to actual technical condition is based on the fact that there is the interaction between possible technical failures of unit and diagnostic parameters which are possible to be controlled. Diagnostic signs of faults may include vibration parameters, technological and regime parameters (loading, temperature, current strength, etc.), admixtures in grease, etc.

Therefore, carrying out monitoring of various parameters characterizing the work of equipment, it is possible to find in time change of technical condition of equipment and to perform maintenance only when there is a real possibility that parameters of equipment go beyond unacceptable limits, that respectively signals about impossibility of further work of object of control.

Maintenance according to the actual technical condition has a number of advantages in comparison with the system of scheduled preventive repairs:

- availability of constant information on condition of the equipment under monitoring (possibility of determination of 'problem' and 'normal'units), allows to plan and carry out maintenance and repair without long and often useless stop, practically to exclude equipment crashes. It is possible to increase productive efficiency by means of introduction of system of maintenance according to actual technical condition;

- forecasting and planning of volumes of maintenance and repair of ‘problem’ equipment, maintenance cost reduction due to minimization of useless repair (increase of inter repair interval) of ‘normal’ equipment. As a result of performance of monitoring of technical condition of units and their maintenance according to actual technical condition off-scheduled amount of works caused by emergency situations, usually makes up less than 5% of total amount of works, and equipment downtime makes up no more than 3% of time spent for maintenance. It is determined that typical expenses on repair in case of equipment failures exceed repair cost at timely detected defect on average by 10 times [2];
- ensuring efficiency of repair due to post-repair inspection. Experience shows that approximately from 2 to 10% of new parts have manufacturing defects which can lead to fast failure of replaced part and equipment failure, and also to cause damage of other normally functioning mates. The defective part or broken assembly technology can be found while testing after repair [3];
- effective planning of distribution of maintenance staff, spare parts, tool, etc.;
- possibility of reduction of standby equipment;
- improvement of labour protection and elimination of violations of ecological requirements. Performance of repair works in extraordinary situation of sudden failure and danger of unplanned production suspension leads to the increase of traumatism [4];
- efficiency of negotiations with suppliers of equipment concerning its warranty and post-warranty repair, restoration or replacement. Registered diagnostic parameters are objective data at solution of controversial questions on reasons of mechanism breakdown.

The idea of equipment maintenance according to actual technical condition consists in providing maximum possible inter repair period of equipment operation due to the use of modern technologies of detection and suppression of sources of failures [3].

This system is based on:

- identification and elimination of sources of repeating problems leading to reduction of inter repair interval of equipment maintenance;
- elimination or considerable decrease in factors negatively influencing inter repair interval or equipment lifetime;
- identification of condition of new or restored equipment in order to control signs of defects reducing inter repair interval;
- increase of inter repair interval and equipment lifetime due to carrying out assembling, adjustment and repair works in strict accordance with technical requirements and regulations.

Nondestructive control methods applied in technical diagnosing of bucket excavators are subdivided into 2 main groups:

1. diagnostic (functional) nondestructive control methods:

- thermal control (TC);
- vibro diagnostic control (VD);
- acoustic emission control (AE).

2. defectoscopy nondestructive control methods:

- visual and measuring control (VMC);
- capillary control (CC);
- ultrasonic control (USC);
- magnetic control (MC).

All types of control and diagnostics should be carried out with the use of standard measuring tools meeting the requirements of the State system of ensuring unity of measurements, and also with use of rules of statistical data processing. To exclude the possibility of operation of parts and units with unacceptable defects suspicious places are checked not less than three times.

We consider in more detail control methods applied at expert inspection of bucket open pit excavators.

When examining industrial safety of open pit excavators visual and measuring control (VMC) method is applied. The purpose of this method is to identify constructive changes in working equipment, rotary platform, main frame, body, etc. (form, surface defects in material and part joints, formed cracks, corrosion and erosive damages, deformations, weakening of joints, etc.) which influence or can influence the safety of operation of excavator [5].

One of dangerous defects detected by VMC are faulty fusions in weld roots, incomplete filling of edge preparations. The main danger of this defect consists in decrease of strength of welded connection, formation of additional concentrators of tension which under unfavourable conditions evolves in main cracks. The deeper is faulty fusion, the higher is the growth rate of main crack.

In parallel with visual and measuring control diagnostic control of excavator equipment can be carried out.

Thermal control (TC) is oriented to assess thermal condition of electric equipment and current-carrying parts depending on conditions of their work and design. It can be carried out according to rated reheat temperatures (temperature rises), excess temperature, defect coefficient, dynamics of temperature change with time, with the change of loading, etc.

At thermal control comparison of results of temperature measurements within phase, between phases, with wittingly operable sites, etc. is carried out. Thermographs with spectral range 8-12 μm and resolution not less than 0,1 ℃ are used to perform TC.

However, the most informative parameter carrying maximum information on condition of assembly of working machine or unit, is mechanical oscillations (vibrations) - elastic waves diffusive in continuum. Information on change of condition of object can be received immediately. These features predetermined the application of vibration method of diagnostics and control (VD) as the main one.

Measurement of vibro acoustic characteristics of bearing supports of mechanisms allows to detect such defects and damages as imbalance and misalignment of shafts; damages of sliding and rolling bearings; damages of gearings inchange-wheel gears; damages of couplings; damages of electric machines [3].

As is well known, the most effective method of vibration diagnostics is continuous monitoring allowing receive in proper time exact and reliable information about equipment condition. This task seems to be especially urgent for fleet of bucket open pit excavators.

When signs of cracks in supporting irons or welded seams of excavator are detected additional inspection by means of one of defectoscopy nondestructive control methods is used:

- ultrasonic control (USC);
- dye penetrant inspection (capillary control).

Ultrasonic control based on the capacity of ultrasonic vibrations to diffuse deeply in solid substances without noticeable weakening and to be reflected from interface of two substances, is the most reliable and simple method of defectoscopy of critical parts and welded connections of excavators. They distinguish 5 USC methods: shadow, resonant, impedance, free vibrations and echo method. The application of ultrasonic phased array is considered to be state-of-the-art technology.

The main advantage of ultrasonic phased arrays is the possibility of program formation of polar pattern of ultrasonic unit, including focusing, insertion point and angle. It allows to realize all control schemes used in multielement systems with linear scan, applying the same PEP. So, for example, the defectoscope X-32 [6] has obvious interface, it is handy in work, and numerous functions realized in it, facilitate and optimize control process:

- presence of 32 active elements provides high spatial resolution that allows to receive distributions and exact defect sizes;
- formation of ultrasonic beams under more than 2000 angles to receive maximum control and resolution area;
- use of up to 128 elements allows to carry out multiplexing (linear scanning);
- presence of modes of one-dimensional echography (A-scanning), two-dimensional echography (B-scanning), linear (L) and sector (S) scanning in real time with analysis of images in all modes of scanning.

Dye penetrant inspection is to determine locations of surface defects with exposed cavity, their directions, extent, nature of development both inbase and built-up metal of welded connections [7].

Acoustic emission control (AE-control) of basic bearing elements of excavator body is aimed at detecting of developing defects in welded seams formed over long period of operation at the expense of accumulation of tensions as a result of cyclic operation mode.

The following elements of construction are to be controlled: boom, top slopes, front and back braces, cross-beam, frame, support, cathead, air receiver for pneumatic system.

Welded seams of basic bearing elements of excavator construction are concentrators of tension, and operational defects in them are caused by various defects of welding, have casual character, both according to the time of origin and location [8].

Acoustic emission control used in real time for operating equipment allows reveal potentially dangerous places in construction, moment of formation of developing defect and its coordinates practically without interruption of work, to say unambiguously about defect development.

Examination of area of hyperactivity detected that cluster of area of damage found itself in swing joint of vertical support of circular section and bottom flange beam. Examination of detected area shows increase in diameter of pin bore in lug, and traces from blows and friction on finger itself.

Thus, by results of acoustic emission control of basic elements of excavator body operational defects the identification of which by traditional control methods demands both considerable financial and labour expenses can be detected. At the same time, it is often difficult to give answer about the need and expediency of repair work performance.

3.Conclusion

Nowadays, the reduction of specific operational costs on maintenance at open pit equipment operation is one of the main reserves of production efficiency increase. Modern methods of technical diagnosing, equipment for their realization and software allow receive with very high level of reliability the opinion about actual technical condition of open pit excavators.

4. References

[1] Diagnosing of technical equipment of hazardous production facilities/ A.N. Smirnov, B.L. Gerike, V.V. Muraviev//Novosibirsk. – Nauka. – 2003. – 320 p.

[2] Shirman A.R., Solovyov A.B. Practical vibration diagnostics and monitoring of condition of mechanical equipment. M. 1996. - 208 p.

[3] Diagnostics of mining machinery and equipment: Tutorial/B.L. Gerike, P.B. Gerike, V.S. Kvaginidze, G.I. Kozovoi, A.A. Khoreshok//M.: IPO 'U Nikitskihvorot', 2012. – 400 p.

[4] Kvaginidze V.S., Zaripova S.N. Statistical analysis and forecasting of industrial injuries at coal-mining enterprises/ GIAB. Appendix 'Yakutia'. Publisher MSMU. – 2006. - #2. – P. 221-232.

[5] RD 03-606-03. Instruction on visual and measuring control, approved by the resolution of GGTN of the Russian Federation from 11.06.03, #92.

[6] Innovative ways of operability assurance of mining machinery on the basis of monitoring of their technical condition/ B.L. Gerike, I.L. Abramov, P.B. Gerike// Kuzbass: Collection of scientific papers. Fascicle of Mining information and analytical bulletin. – 2008. - #7. – P. 228-240.

[7] Kalinichin N.P., Kuleshova G.P. Nondestructive control. Capillary method/M. – publisherIntroscopy Research Institute. – 2002. – 101 p.

[8] Assessment of technical condition of supporting irons of walking excavators according to parameters of acoustic emission signal/ B.L. Gerike, S.I. Protasov, A.V. Menchugin, P.V. Buyankin// Mining equipment and electromechanics. – 2009. - #5. – P. 25-30.

Evaluation of Explosion Protection Means of Mine Electrical Equipment for Operation in Excavations of Coal Mines

EFREMENKO VLADIMIR, BELYAEVSKY ROMAN

Energyinstitute, t.f. Gorbatchevkuzbass State Technical University, Kemerovo, 650000, Russia

Abstract
Information of ensuring explosion-proof properties of mine electrical equipment is one of important problems of ensuring safe operation of electrical equipment in coal mines are provided. It is shown that this process is very difficult and a little studied. The analysis algorithm and identifications of influence of defects of constructional elements of a cover on explosion protection is offered. The analysis of existing normative documents is carried out and the directions of researches are offered.

Keywords: explosion protection, mine electrical equipment, explosion safety, defect, coal mine

In excavations of coal mines always there is a potential danger which under certain conditions can pass into the real. So, in particular, this danger can arise at coincidence of such events as existence in developments of the explosive atmosphere and a source of initiation of explosion which can be mine electrical equipment with faulty means of explosion protection. According to GOST 27.310-95, the equipment is reliabile . The analysis of types, consequences and criticality of refusals" loss of explosion-proof properties of electrical equipment can be referred to the IV category – "refusal which quickly and with high probability can cause a significant damage for the object and (or) for environment, death or heavy injuries of people, failure of performance of an objective" [1].

Explosion protection of the mine electrical equipment established in excavations of mines, is provided, generally application of a special design – the explosion-proof cover which explosion-proof properties it is reached due to use of special constructive elements: explosion-proof crack between separate elements of a cover, application of spring washers in knots of fastening, sealing plugs of cables, caps not used inputs, security rings round fastening bolts, etc.

Distinctive feature of ensuring explosion-proof properties of electrical equipment is that explosion protection is provided with set of a working order of all elements. Defect of one of them can bring, with a certain probability, to loss of explosion-proof properties and, besides with a certain probability, to explosion or a fire in excavations. It should be noted that control and diagnostics of emergence of defects of separate elements is difficult as many defects can't be measured in work process. Besides, defect of any element of explosion protection doesn't lead to transition of electric equipment to a non-working state (stopping the engine, shutdown of the electric device) but only translates it in faulty, but operating state.

In the coal industry a number of normative documents [2, 3, 4] which define an inspection routine, audits of mine explosion-proof electrical equipment, including means of explosion protection works now. However in these documents critical parameters of defects of the explosion protection which excess demands an electrical equipment conclusion from operation and adoption of a certain decision on its further safe operation (utilization, use out of an explosive environment, repair, prevention and adjustment) aren't established.

The analysis of a condition of explosion protection means consists in identification of the factors influencing explosion protection, and estimates of their importance as the factor having impact on explosion safety. It is known that any event, in this case explosion protection violation, is seldom caused by the only reason. Most often sources of emergence of defects are: the person (man) – the car (machine) – a method (method) – a material (material) – so-called 4M. In the conditions of excavations to them environment conditions, the natural phenomena, etc. are added.

The analysis of a condition of explosion protection of mine explosion-proof electrical equipment includes:

1.Choice of set of indicators of the separate constructive elements providing explosion protection, and determination of critical size of defect at which excess there is a high probability of formation of real danger (explosion, a fire).

2. Development of mathematical model and the program computer system for an assessment of probability of violation of explosion protection, both on a separate element, and on their set.

3. Carrying out necessary researches and tests in laboratory and working conditions for the data acquisition, characterizing process of loss by electrical equipment of explosion-proof properties.

The researches conducted by us on a number of mines of Kuzbass[5], are allowed to establish that loss of explosion-proof properties of mine electrical equipment is influenced by the following defects:

—absence or breakdown spring washers on fasteners;

—rust on explosion-proof surfaces;

—damages of rubber sealing rings to cable inputs;

—lack of caps on not used cable inputs;

—the increased gap between explosion-proof surfaces;

—damage of a carving of fasteners;

—mechanical damages of elements of a cover;

—damages of security rings on covers of introduction offices;

—damages of insulators through passage.

The histogram of distribution of probability of emergence of explosion protection defects for 672 units of electric equipment is given in fig. 1.

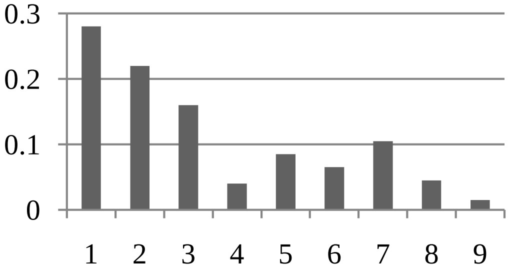


Fig. 1: The histogram of distribution of probability of emergence of explosion protection defects

The conducted researches are allowed to establish that decrease in explosion-proof properties of mine electrical equipment is influenced by various defects of constructional elements. Most often such defects of explosion protection as absence or breakage of spring washers, a rust on explosion-proof surfaces, damages of sealing rings (about 66% of all damages), but it doesn't mean meet that these defects are most dangerous to loss of explosion-proof properties. For example, such defect as damage of an insulator through passage meets seldom (1.3%), but on the consequences is more dangerous as in this case possibly short circuit on the case with possible emission of an electric arch outside of the introduction device, especially if thus there are no caps of non-working inputs or are damaged there (do not correspond) sealing rings. Also on weight of consequences and formation of dangerous situations mechanical damages of covers are the extremely dangerous. It should be noted that development of one defect (for example, absence or damage of spring washers) leads to appearance of another (increase in a gap between explosion-proof surfaces). That is in certain cases there is a coherence of events (defects of elements of explosion protection) which develop both in parallel (independently) from each other, and is consecutive. Development of one leads to appearance of another.

For an assessment of level of explosion safety of electrical equipment it is possible to use the following technique [6].

By consideration of level of explosion safety of electric equipment it is considered three states:

—normal when the condition of separate elements of explosion protection allows to exploit him without any restrictions (2);

—pre-emergency when correcting influences directly in an electrical equipment installation site (replacement of washers, cleaning of explosion-proof surfaces of a rust, installation of sealing rings and caps, etc.) are required after which the decision on further operation of electric equipment is made(1);

—emergency when a condition of explosion protection such is that is required or repair in the specialized organizations (restoration of mechanical damages, replacement of separate details), with the subsequent decision on further operation (for example, as mine normal, removal a sign of explosion protection and further operation as not explosion-proof) or utilization (0).

The condition of explosion protection can be estimated:

$$F(S_i) = \begin{cases} 2, S_i < S_i^1; \\ 1, S_i^1 \le S_i < S_i^0 \\ 0, S_i \ge S_i^0; \end{cases} \qquad (1)$$

where n – quantity of observed elements of explosion protection; S_i – the actual value of a condition of $i$element of explosion protection; S_i^1, S_i^0 – value of pre-emergency and emergency threshold condition of i element of explosion protection.

Further it is necessary to define the importance of each element in the general scale of values, to find out "specific weight" in the general value of indicators of refusal of explosion protection. The most acceptable for the solution of this task, in our opinion, is the FMEA method (Failure Mode and Effects Analysis) [7]. Thus define:

—list of potential defects of explosion protection;

—potential reasons of emergence of these defects;

—potential consequences of the revealed defects;

—possibility of control of the revealed defects.

The FMEA method is expert method. Experts in 10-ball system estimate above the listed parameters. Thus the highest point is appropriated to defect with the most serious consequences, with the greatest probability of emergence and it is the most difficult revealed.

For realization of this method it is necessary to define:

1. Rank (point) of the importance of each defect of explosion protection and possible consequences on its influence on level of explosion protection (R).
2. Probability of emergence of this or that defect of explosion protection (E).
3. Probability of detection of defect at electric equipment survey (S).

The Complex Risk of Defect (CRD) of explosion protection can be defined as CRD = R×E×S. According to recommendations [7] at value of CRD ≥ 100 … 120, the explosion-proof electrical equipment has to be immediately taken out of service, is lifted on a surface and sent to the specialized repair organizations for carrying out repair and correcting actions or utilization. At CRD ≤ 40 operation of electric equipment can be continued without restrictions. At 40<CRD< 100explosionrisk of losses defined as the average. In this case it is necessary to carry out repair work in the conditions of our workings (e.g. installation of lock was hers for fastening parts, rubber sealing rings in the cable gland sand plugs for unused cable glands). But since in this case we have a very high risk(IV category according to GOST27.310-95) consequences of potential defects means of protection, the value of CRD should be toughened and determined by the results of research.

The decisions made by experts have to be reflected in the book "Registration of a Condition of Electric Equipment and Grounding" with the conclusion of the chief power engineer of mine.

Thus, it is necessary to consider that for receiving the most reliable results the assessment requirements of an expert have to be imposed to members of expert group, characterizing their knowledge and qualification in the matter. The quantitative structure of expert group can be determined by expression:

$$N \geq \frac{h^2 r_a r_o}{\Delta^2} \qquad (2)$$

where h = 0,95 – confidential coefficient; r_a, r_o– a share of sample units with existence and lack of the set defect; Δ – an error of a representativeness.

At r_a = 0.95, r_o = 0.05, Δ = 0.05 minimum number of experts will make 18 people.

For an assessment of comparative influence of separate elements on the general level of explosion protection the expert method of an assessment is used. For what the matrix comparative (in pairs) characteristics of defects of elements of explosion protection is formed:

$$\begin{matrix} 1 \\ 2 \\ \vdots \\ \vdots \\ n \end{matrix} \begin{bmatrix} 1 & \cdots & \cdots & \cdots & \gamma_{1n} \\ \gamma_{21} & 1 & \cdots & \cdots & \gamma_{2n} \\ \vdots & \cdots & 1 & \cdots & \vdots \\ \vdots & \cdots & \cdots & 1 & \vdots \\ \gamma_{n1} & \cdots & \cdots & \cdots & 1 \end{bmatrix} V_i = \frac{\sum_j^n \gamma_{ij}}{\sum_i^n \sum_j^n \gamma_{ij}} \qquad (3)$$

where V_i – the specific weight of i element of explosion protection in system of ensuring explosion safety of electric equipment; γ_{ij} – the conditional importance of i element of explosion protection in comparison with j element.

The integrated assessment of a qualitative condition of explosion protection is determined by an indicator assessment

$$B_{ij} = \begin{cases} 2, \sum_i^n V_i^2 \leq R_2; \\ 1, \sum_j^n V_i^0 < R_0 \text{ и } \sum_i^n V_i^2 > R_2; \\ 0, \sum_i^n V_i^0 > R_0; \end{cases} \qquad (4)$$

where V_i^2, V_i^0 – the specific weight of i element of the explosion protection which is in area of normal and emergency values respectively; R_2, R_0 – the coefficients characterizing level of achievement of a normal or accident condition respectively. It is possible to assume that if the total specific weight of defects of all elements of explosion protection will make no more R_2 from the sum of all defects, the condition of explosion protection can be estimated as accepted or normal. At the specific weight of all defects of more R_0, the condition of explosion protection is emergency. In limits between the areas defined as normal and emergency there is a pre-emergency condition.

Besides, it is necessary to create the program computer system (PCS), capable to calculate and simulate probability of emergence of accident taking into account external factors influencing electric equipment and a condition of elements of the design providing explosion protection. PVK has to consist of the following blocks:

— the information and analytical block providing collecting and preprocessing of information on a condition of means of explosion protection;

— the block of standard and technical documentation, including software of procedures of collecting, processing and adoption of the decision;

— the block of examination of the received results of preprocessing, development of operating decisions and recommendations, including about possibility of further operation of electric equipment;

— the block of modeling of process of emergence and development of an emergency (explosion) depending on a condition of explosion protection and environment.

By results of the analysis of a condition of means of explosion protection, except the operational actions directed on decrease in probability of possible explosions, it is necessary to consider possibility of constructive change of mine explosion-proof electrical equipment. So, we[8, 9] offered the design of explosion-proof electric equipment which is almost excluding possibility of explosion in a cover. The carried-out research and development, and also tests of prototypes confirmed prospects of this direction in increase of safety and reliability of electric equipment for explosive rooms and mountain developments.

References:

[1] GOST 27.310-95. Reliability in equipment. Analysis of types, consequences and criticality of refusals.

[2] GOST RIEC 60079-17-2010. Explosive environments. Part 17. Check and maintenance of electric installations.

[3] Instruction on survey and audit of mine explosion-proof electrical equipment.

[4] The leading document defining an order of survey of a condition of means of explosion protection of mine explosion-proof electrical equipment and establishment of a condition of its further safe operation.

[5] Razgildeev G. I. The characteristic of damageability of means of explosion protection of mine explosion-proof electrical equipment/G. I. Razgildeev, V. M. Efremenko, V. M. Druy//Health and safety of the enterprises in industrially developed regions: Materials VII of the International scientific and practical conference. V.1. – Kemerovo: KuzSTU, 2007. – P. 98-101.

[6] Senderov, S. M. Assessment of energy security of Siberia / S. M. Senderov, M. B. Cheltsov// Power Academy. –2008 . – No. 2. – P. 92-99.

[7] GOST P 51814.2-2001. Method of the analysis of types and consequences of potential defects.

[8] Copyright certificate851516 USSR. Explosion-proof electric equipment/ G. I. Razgildeev, S. L. Rusov, M. V. Horunzhy, V. M. Efremenko (USSR). –27.03.1981.

[9] Copyright certificate1364198 USSR. Explosion-proof electric motor / B. V. Shush pannikov, V. M. Efremenko, G. I. Razgildeev (USSR). –01.09.1987.

Part IV

Construction safety in mines and underground engineering

To the Question of the Destructed Rock Mass Movements Regime Assessment

KHARKOVSKYI Victor S.[1], PLOTNIKOV Valery M.[1], KOMLEVA Eugenia V.[1], KOGAY Olessya A.[1],KOROBKINA Anna S.[2], HARLAMOVA Anna V.[3] ,GONCHAROV Yuri N.[4], BALIKBAYEV BekturKh.[4]

(1.Karaganda State Technical University, Mining Faculty,The department of "Mine aerology and a labor safety" 100027, Karaganda, Kazakhstan;2.Karaganda State Technical University, Mining Faculty, Methodist of International office 100027, Karaganda, Kazakhstan;3.Karaganda Research Institute of Industrial Safety, Branch corporation 100027, Karaganda, Kazakhstan; 4.JSC"EEC" "Vostochniyt",141202,Ekibastuz,Kazakhstan)

Abstract: The article proposed equation criteria specifying the interaction force field with the medium. Based on the proposed regularities we suggested the medium parameters changes dependences and momentum and energy characteristics, the resistance of the medium on which the formation hazards equation were made. A device for rock mass overloading in a large volume, with a reduction of the hazards emission into working zone by two rates was suggested.

Key words: cargo flow, safety criteria, the conveyor unit, the porosity of the medium, the flow state, fluent.

1.Introduction

International practice recommends conveyor transport for conditions of high power open pit mineral deposits. Advantages are threading movement of raw materials, a relatively large length of transportation, the ability of bulk material movement angle to 20 ° which allows reducing the delivery path compared to rail and automobile road 6-8 and 3-4 times, increase the height of the mining face and apply the technique of greater productivity. However, at the same time there is an increase of shattered rock mass hazards allocation and creation of the emergency conditions of intermediate filling containers intended for the localization of the active technological processes components: dust, gases, radioactive substances, and the like. For solid and liquid mineral output hazards emission accompanied by a translation of the raw material definitions in special aerodynamic condition-aerosol, which manifests overload destroyed the rock mass and generates dust flow, the concentration of dust in the working area is greater than 5,000 mg/m3, which determines the optimal flow regime movement of destroyed rock mass.

2.Characteristic of the work

Criteria setting for technical process evaluating safety is a major engineering challenge and requires the linking of a random process measure probability in the settlement periods and volumes of production, based on the indicators of the kinetics and medium resistance to external effects, i.e. regularities

$$\frac{\text{Эк}}{\text{J}} = R \qquad (1)$$

$$R = 2U_{\text{g}} \qquad (2)$$

where $Эк$ - the kinetic energy of the external load power ;J - the pulse impact on the medium;R -resistance of the medium, estimated as twice the value of the dynamic speed;$2U$g - dynamic flow rate .

These dependences [1, 2] determine the movement of the medium elements to considered conditions of destroyed mountain mass or fluent, conventional liquid filling volume of space, determining fine particles emissions beyond transported stream.

If the technological system is physical and chemical or a similar space, the arrangements for the transfer of energy and mobility of elements determined by the laws of Einstein and has the form shown as [2, 7, 8]

$$D = aT \tag{3}$$

$$a = \frac{1}{b} \tag{4}$$

Where D is thediffusion coefficient, medium circulation characteristics, the mobility of the considered element, the internal friction of the received energy level;T is the energy of the medium mobility; b is the binding energy between the elements of the medium;

a is the medium mobility.

In this case, the analyzed environment should be considered as a multi-phase, skeleton forming pseudo-solid and pseudo-liquid and at its mobility level determining the system destruction.

$$a_f = \frac{\beta_1 k(1-m_0)}{1-\beta_1 k(1-m_0)} \tag{5}$$

Where $k(1-m_0)$ - all-round medium compression module; m_0 –the porosity the system; β –dimensionless parameter characterizing the volumetric change of medium(index 1 belongs to solid, index 2 belongs to liquid).

In the submission of Y. I. Frenkel[9] parameter a_f characterizes a disturbance of porosity defining fluent mobility (viscous fluid) and in apparently solid phase in motion relative to the standard.

Established[3,9] for rocks during compaction within 0,92-0,72 sample and its physical parameters, as the all-round compression modulus is constant.

For these conditions, shattered rock mass displacements estimated according to the condition of double phase medium compressibility characterized with deformation of shattered rock mass volume with the bulk material parameters characteristics.

For the analyzed conditions the failure of small particles and transfer them into aerosol produced by the deformation of the destroyed rock mass and vortex fluent diffusion. Therefore, based on the conditions of disclosure concept of "dynamic speed" [1, 2, 4, 6-9] we have regularity

$$\sqrt{\frac{\tau}{\rho}} = \Gamma\, \text{Кк} \tag{6}$$

Where τ –displacement of medium tension;Г - fluent circulation;$К_к$ – coefficient of rolling friction.

Depending on the specific conditions of external force field adopted equation engineering calculations for the assessment of the circulation can be estimated by the following fluent indicators: kinematic viscosity, diffusion coefficient, index of medium thermal conductivity.

Circulation, or rather its analogues, concrete medium fluent: viscosity, diffusion, thermal diffusivity, i.e. reverses flow characteristics:

$$\Gamma = \frac{3\sqrt{2}\pi d_2^{\,2}}{J_i} \tag{7}$$

Where d_2 is the surface characteristic of the pore space vortex, the size of the pore volume (solid) ; J_i is the pulse impact of an external force field to the unit volume of destroyed rock mass pore space (liquid).

Studying the conditions of mass transfer V. M. Casey [4] proposed the characteristic of an external force field its impulse component and circulation as a criterion for the liquid substances transfer - to be Lewis criterion in particular:

$$\frac{\omega dn}{v} = Le \qquad (8)$$

Where ω is the frequency of the force field impact; pulse characteristic of the fluent; v is kinetic viscosity of the medium.

This allows determining the pattern of the force field impact on the porous medium with following dimensionless equation:

$$\mathrm{Re} \cdot Sh \cdot Le = 2 \qquad (9)$$

where *Sh* is Strouhal number, stationary criterion of the homochromatic process;Re is Reynolds number, friction regime of the destroyed rock mass.

The characteristic mode of transportation destroyed mass flow gets the main interests. In general, the evaluation of the flow binding is determined by slit distance between its elements, i. e.

$$\mathrm{Re} = \frac{u_n d_1}{v_2} \qquad (10)$$

where *Un* is the flow rate.

For the conditions of small fractions transfer, the determining factor is the shown size of the destruction elements separation, i. e. the condition of the slit formation, which was laid to the evaluative indicator, the regularity takes the following form:

$$\frac{d_2}{d_1} = \frac{v_2 r_e}{u_n} \qquad (11)$$

Set at a value of Reynolds number up to 10 - the mode of destroyed rock mass movement is connected; from 10 to 2100 is transitional and when the number is bigger than 2100 - elements of destruction have no connection with each other.

For the connected mode defines the air conditions:

$$\frac{d_2}{d_1} \le 0.01 \qquad (12)$$

Strouhal criterion is a characteristic established traffic type and represents the flow rate conditions change for a certain period of time.

$$Sh = \omega^2 d_2/\mathrm{Un} \qquad (13)$$

The assessment index can be taken for the continuous mode - 0, 12, intermediate - 0, 16, turbulent - 0, 21

Transfer of energy and matter with moving means (liquid or gaseous) in the criteria form of theoretical developments, criterion [4, 7, 9, 10], proposed to make according to the following dependence evaluation criterion:

And to the account of aerosol stream movement according to the theory of mass transfer [4] determined by the condition:

$$St \cdot \mathrm{Re} \cdot \mathrm{Pr} = 4.364 \qquad (14)$$

Where St – Stanton number characterizes the fluent friction conditions and skeleton forming space - the hydraulic friction coefficient;*Pr*– the assessment conditions of transferring energy level of sliding friction into rolling friction (fluent physical characteristics).

Stanton criterion characterizes the loss of energy to overcome friction.

$$St = 0.5 \cdot Cf \qquad (15)$$

where C*f* is the local friction index.

Prandtl number is determined by the fluent medium and characterized by its physical properties for the analyzed conditions – air.

$$\mathrm{Pr} = \frac{v}{a} \qquad (16)$$

Where *a* is thermal diffusivity.

All this allows dependences [9] and [14] combine into the system of the destroyed rock mass displacement regime criteria assessment.

$$\begin{cases} \text{Re} \cdot Sh \cdot Le = 2 \\ St \cdot \text{Re} \cdot \text{Pr} = 4.364 \end{cases} \quad (17)$$

Which can divide the overload into three zones (or rather the conveyor unit) gutter, and a lower receptor, produce their aerodynamic separation and determine the optimal stream location in each of them.

Experiments of condition [1, 3, 5, 6,] the smallest emission of dust into working area occurs in a shattered rock mass laminar movement, at a high speed of bulk material movement it is necessary to remove the gutter from the unloading head of the upper conveyor, height separation assessment of the gutter and a lower belt destruction which are measured by the system (17).

These defined features determine the localization of the resulting hazards technological processes.

On this basis, the reloading device was developed entered in force on the territory of the section "Vostochniy" JSC "EEC" [5]: Performance 600-1500 t / h; Height overload 4-6 m; cargo flow moving horizontally 4～6 m/s; the average size of shattered rock mass - 300mm; belt width - 2～4 m.

The degree of dust aerosol emission referenced to the conveyor unit is determined by the condition of reloaded material contact with the medium a confined structure space.

Thus, the disruption of particles occurs from the contiguity surface of the contact layers. Consequently, the layer mode, which the new conveyor unit was designed for, characterized by a minimum aerosol output because the contact is only possible on the top. At the free pieces fall in the shelter the disruption is made from the surfaces oriented toward reloaded material fall, which significantly increases the large fractions aerosols output, which is typical for dust settling chambers [6].

Applied conditions of adopted reload the boundary layer thickness does not exceed 0.027 mm, which corresponds to the particle size 20km.

The device worked for more than two years in the process chain without emergency. The characteristics of working places dustiness in the comparative assessment of the project device operation in comparison with regulated by KSTU professionals, is shown in table 1.

Table 1: Comparative assessment of the device operation, recommended by KSTU professionals and design

The device type	Measuring area	Dustiness, mg/m^3		
		Maximum	Medium	Minimum
Design	Bottom	7900	6123	5480
	Top	4330	3686	3252
NewreloadingdeviceKSTU	Bottom	25,6	15,03	6,7
	Top	20,6	12,24	5,5

Table 1 shows that the calculation of all patterns allows to manage the process by which hazards are formed and have access to the work zone, herewith the concentration of dust was reduced by more than two rates.

3.Conclusion

The abovementioned results allow the following concluding:

1. The equation of the criteria assessment process is proposed for technological processes safety assessment based on the external energy arrangement, impulse characteristics response and resistance of medium.
2. The regularities of medium features change were shown due to the fundamental features of the material and fluent.

3. Implementation of the received recommendations will reduce the hazard emission on example of dust aerosols by more than two rates.

4. References

[1] Methods of advanced coalbed dust formation reduce / A. E. Perezhilov, E. Y. Dikolenko, V. S. Kharkovskiy, etc. M.: Nedra, 1995, p.408

[2] Metodology of Manufacturing Hazards and Rates Assessment/ Viktor S. Kharkovskiy, Valeriy M. Plotnokov, Nicolay A. Drizhd, Evgeniya V. Komleva, Anna V. Kharlamova 'Europen Researcher' № 1-14 August 2012.

[3] O. V. Abramov, A. N. Rosenbaum Prediction of the technical systems state. M.: Science 1990, p.126

[4] V. M. Case Convective heat and mass transfer. M.: Energy 1972, p.448

[5] Patent number 27023 KZ A4V62 69/18 (2006.01)

[6] Satarin V. I., Purley S. B. Movement and dedusting gases in the cement industry. M.: Gosstroiizdat, 1960, p. 305

[7] L. D. Landau, E. M. Lifshitz Theoretical Physics. T. Hydrodynamics VI - M.; Science 1986 - 736 p.

[8] The rheology. Theory and Applications / F. Eirich, A. Bondi, P. A. Rebinder and others. M.: publishing house Inlit 1962. p. 387-491, 459-508, 812-818.

[9] Mechanic of saturated mountain mediums / V. I.Nicholas, K. S. Basniev, A. T. Gorbunov, G. A. ZotovNedra 1970 p. 239.

[10] L. G. Loitsyansky Fluid and gas mechanics. - M.: Science, 1973, 547p.

Simulation of Stress-Strain State of The Reinforced Soil Foundation for Structures

PROSTOV Sergei M., SOKOLOV Mikhail V.

Mining Institute, T.F. Gorbachev Kuzbass State Technical University, 650000, Kemerovo, Russia

Abstract: Therein there is formation of algorithms database of stress-strain state of reinforced soil foundations and optimizing the main parameters of the computer model. The analysis of the results of calculations for the foundation strip, slab and columar type on homogeneous and layered the basis.

Keywords: soil foundation, foundation, distortion, stress, stratification, modeling

1.Introduction

Pressure injection techniques [1] and electrochemical fixing [2] of weak saturated soils are very promising in underground, surface and hydraulic engineering. Processes in the area of consolidation, are very complex, they are dedicated to the study of a number of works. Until now the aspect of the interaction geo-mechanical fixed zone adjoining its natural array and structural elements is poorly studied. This paper [2] attempts to make analytical solution of problems in the elastic and elastic-plastic formulation. The results can be used in practice with sufficient accuracy only under ideal conditions, such as a homogeneous medium, winze circular section shell of equal thickness.

To solve the applied and practical problems of the issue under consideration, it's reasonable to use numerical methods, while application of Alterra, included into the software package Geosoft is promising. The main advantages of this program are as follows: the possibility of solving both two - and three-dimensional problems; implementation of nonlinear (elastic, plastic and elastic-plastic using Mises criterion) and rheological models; possibility of accounting for heterogeneity of the environment (geological structure, geometry and properties of the docking region, structural elements).

This paper [3] reviews main methodological aspects of modeling of geo-mechanical processes in the grounds of the post footing, strip, slab and pile foundations.

As part of the concept developed in this paper we present algorithms for data bank, detailing the parameters of the computer model and some simulation results.

2.Work description

The object of study is the state of the soil mass surface mining structures having structural changes upon application of loads in the form of various types of foundations. For an analysis of its stress-strain state a database of state parameters array (normal and shear stress σ_x, σ_z, τ_{xz}, deformations vertical and horizontal displacement u and v) was formed according to the enlargement algorithm (Fig.1). In the framework the effect of different soil deformation parameters before and after fixing (modules of deformation E and E_y, Poisson's ratio ν и ν_y, and the cohesion C и C_y, angle of internal friction φ and φ_y respectively), the size and location of zones ECP, geological structure and parameters of the foundations are reviewed.

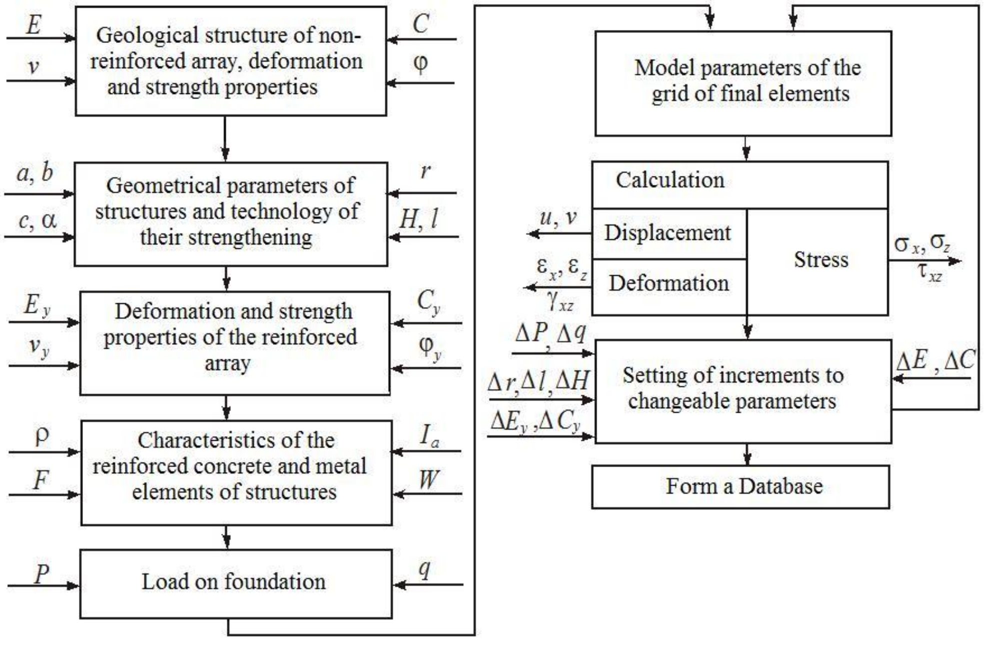


Fig. 1: Enlarged algorithm of formation of the source database:
a , b - width and height of foundation; c - depth of foundation; α - angle of cut slope; H - radius and height of docking zone, respectively; l - distance between fixing zones; P , q - concentrated and distributed load along the edges of foundation; ρ - density of material for foundation; F , I_a , W - parameters of sole foundation

At the initial stage of computing geo-mechanical research study, an important aspect is the substantiation of initial parameters of the basic model, which must comply with the maximum calculation and can be determined based on the primary software calculations estimate areas by establishing of the basic parameters of the model as follows: width B_m , height H_m and number of elements N .

The main criterion for selecting of the model parameters is the error δ , defined as the relative difference of simulation results and theoretical reference values determined by classical methods of calculation of the foundations [4, 5]. For the analysis we used etalon foundation (stamp) under the most adverse ground conditions.

Fig.2 shows the obtained results of calculations of the dependence of error δ from the model parameters B_m , H_m , N , so we can determine the field of rational foundation model. In particular, the analysis of the graphs shows that changes of δ occurs by polynomial or logarithmic dependence, and setting the value of the maximum error on the level $\delta = 5\%$, you can define the minimum values of the above parameters.

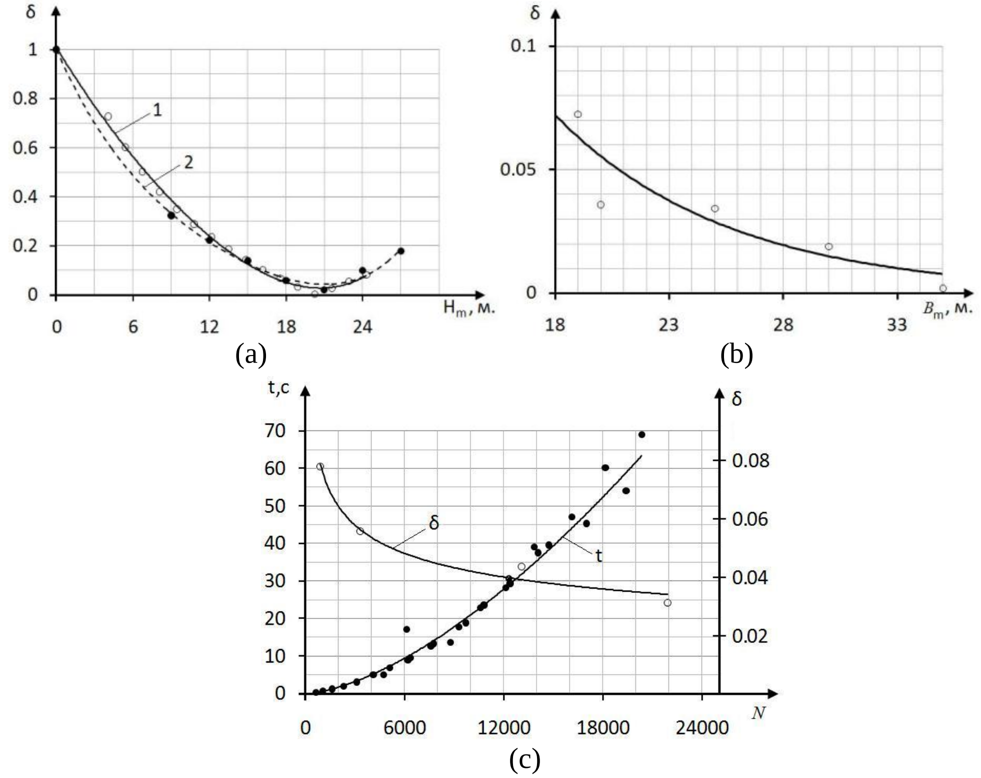


Fig.2: Dependence of δ from H_m (*a*) δ from B_m (*b*) N from δ and time *t* (*c*)

1 - at a ratio of $H_m / B_m = 4:3$; 2 - at $B_m = 20м = const$

The algorithm for determining of the main parameters of the calculation of the signal model is shown on Fig.3.As part of the formation of the analytical database modeling results are obtained in the form of contour of the principal stresses σ_x, σ_z, τ_{xz} strain ε_x, ε_z, γ_{xz}, and displacements u and v.

Some results of the calculation for the main types of foundations are shown on Fig. 4.The stress-strain state of the strip foundation was studied in more detail, as this foundation has a distinctive element - the sole, and the conditions of its modeling as close as possible to the conditions of the plane problem. The primary analysis showed that within the linearly deformed base there is a proportional dependence between the stress and strain that is the criterion validity of the results. Stress distribution σ_x, σ_z, τ_{xz} in the soil body is uniform with the formation of the zone of maximum stress under the foundation.

The interest is geo-mechanical state of the layered base for different deformation properties of layers and angle of inclination β of its border.

The dependency graphs of vertical deformation ε_z on Fig.5, show that the inhomogeneous strain ε_z distribution is characterized by displacement $\Delta\varepsilon_z$ at the boundary layers having different values E, and ranges of changes ε_z of both layers and $\Delta\varepsilon_z$ is dependent on the ratio E_1/E_2 and the angle of inclination of the boundaries of layers β.

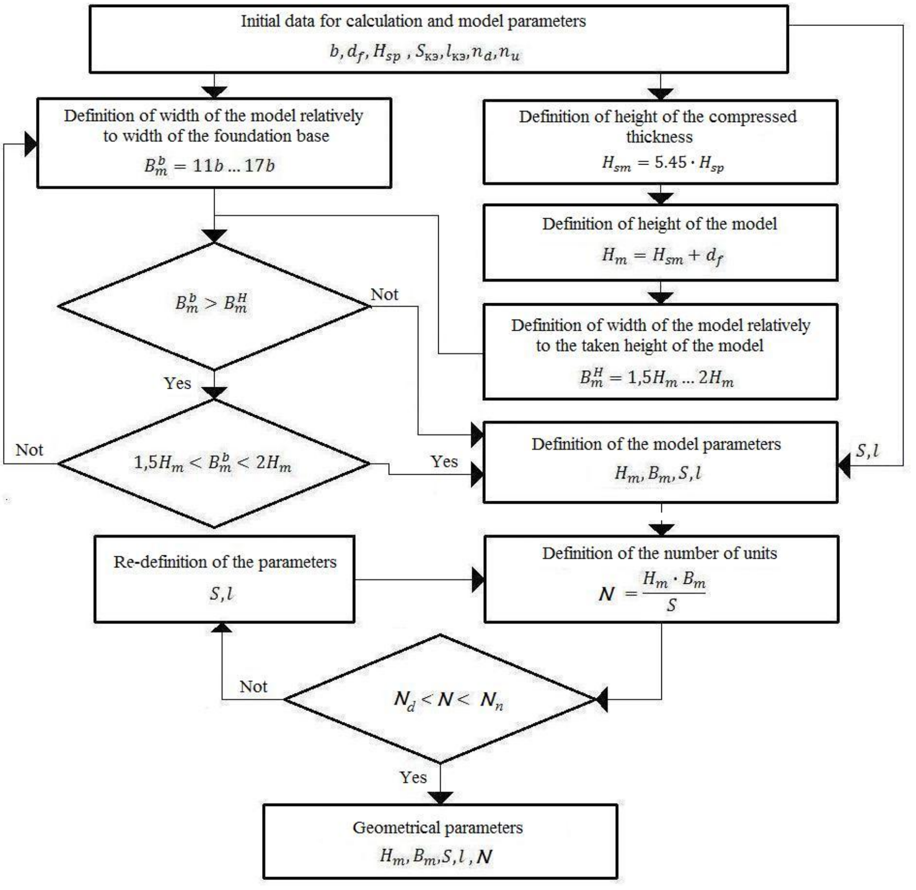
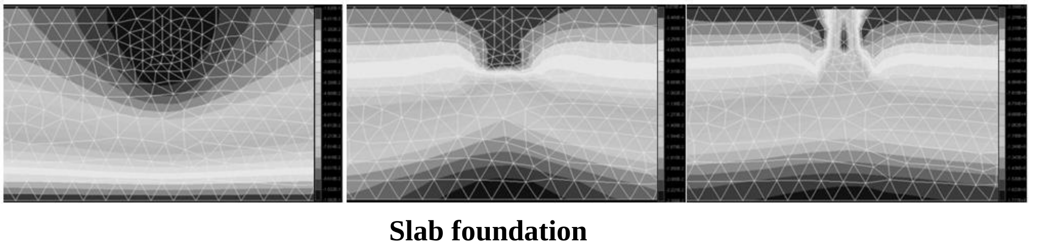


Fig. 3: Algorithm to determine geometric parameters of the model:
d_f - depth of foundation; H_{sp} - theoretical value of height of the compressible strata adopted regarding the load; S, l - area and length of elements; N_d, N_u - lower and upper limit of the number of elements

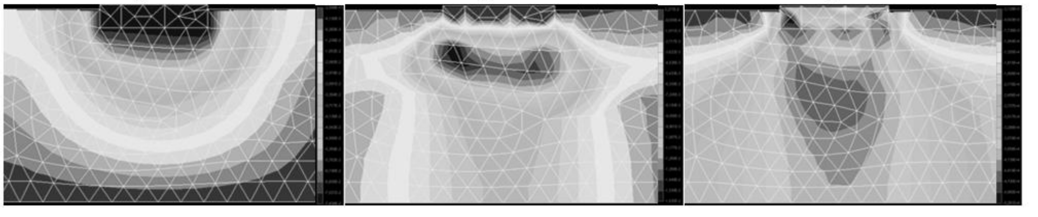
Strip foundation

a *b* *c*



Slab foundation

a *b* *c*



Post Footing

a *b* *c*

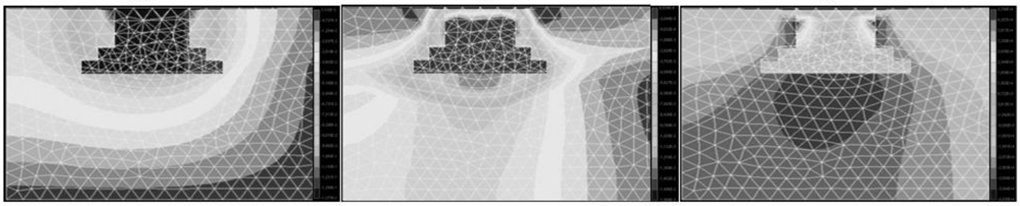
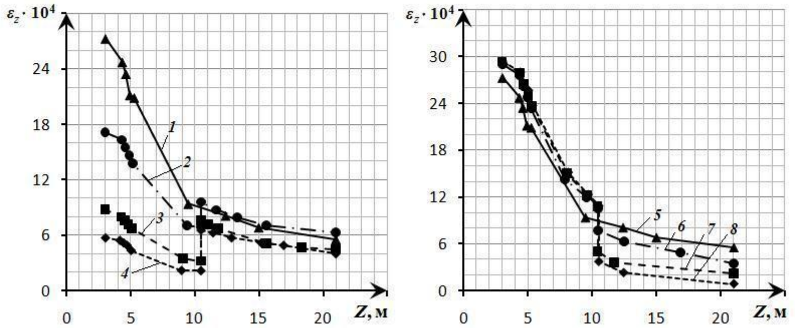


Fig. 4: Results of calculation of vertical displacements u (*a*), strain ε_z (*b*); stress σ_z (*c*) for the main types of foundations

Angel of deposition layers $\beta = 0^{\circ}$

(a) (b)



$\beta = 18^{\circ}$

(a) (b)

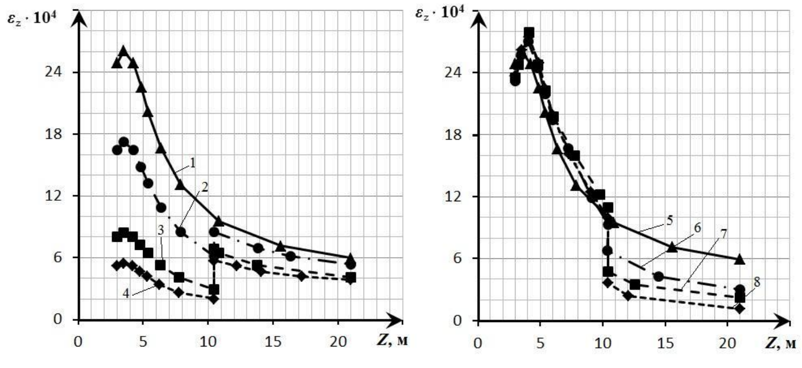


Fig. 5. Dependencies of vertical deformation ε_z of the coordinate Z at low bottom (*a*), top (*b*) layer depending on the ratio of the deformation modulus E_1/E_2 :
1 – 1,0; 2 – 1,5; 3 – 3,0; 4 –4,6; 5 – 1,0; 6 –0,67; 7 – 0,33; 8 – 0,22

Dependencies $\Delta\varepsilon_z(E_1/E_2)$ (Fig.6) are complex, it is necessary to take into account when justifying the foundations of rational parameters.

The main practical use of the database obtained as a result of simulations is as follows: the establishment of regularities of the formation of the stress-strain state of structures at the base in the most typical cross-sections; establish dependencies major technological and structural parameters of the foundations of the variable parameters of the model;

recommendations on specific technological and design parameters for the design of foundations, construction and repair work.

(a) (b)

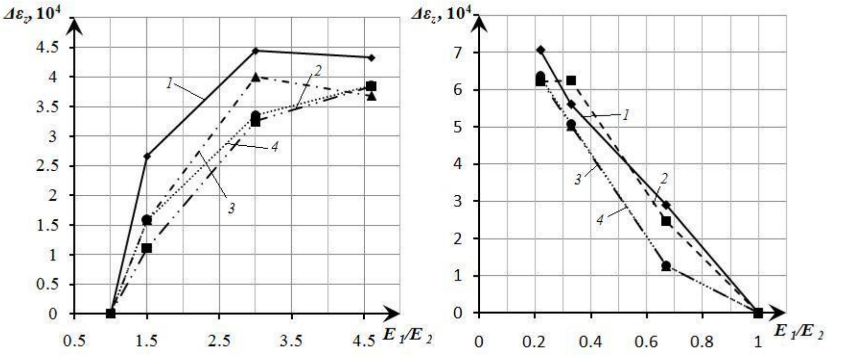


Fig. 6. Dependence of the value of displacement of the vertical deformations $\Delta\varepsilon_z$ from strain modules ratio E_1/E_2 at weak bottom (*a*), top (*b*) layer and an inclination of layers β : 1 – 0 °; 2 – 6 °; 3 – 12 °; 4 –18 °

3.Conclusion

Generalizations of these results allow making the following conclusions:

1. Purpose of computer modeling stress-strain-state groundwater strengthened by ground structures is the formation of a database of displacements, strains and stresses, in this case as a priori information using geo-technical soil characteristics, geometrical and physical-mechanical parameters of the docking zones, and reinforced concrete structures.
2. While modeling it’s necessary to take rational computer model parameter ranges: width, height, number of elements, using as a criterion for calculating the error and the length of the computing.
3. One of the major factors influencing the stress-strain state of subgrade is its bedding, since the boundary layer has abrupt changes of strain and stress, depending on the ratio of moduli of deformation and inclination of the border.

4.References

[1] Prostov S.M., Integrated monitoring of the processes of high-pressure injection of soil / S.M. Prostov, V.A. Haymaylaynen, O.V. Gerasimov. - Kemerovo; Moscow: Kuzbassvuzizdat. - ASTI 2006. – 94p.

[2] Prostov S.M. Electrochemical grouting / S.M. Prostov, A.V. Pokatilov, D.I. Rudkovskiy; RAEN. - Tomsk University Publishing House Том, 2011. – 294 p.

[3] Pokatilov A.V., Computer modeling of geo-mechanical processes at electrochemical grouting of the ground foundations of structures / A.V. Pokatilov, S.M. Prostov, S.A. Ivanov // Vestnik. KuzSTU. - 2013. - # 4. - papes 61-65.

[4] Kushner S.G., Callsilation of strain of foundation for buildings and structures / S.G. Kushner; Zaporozhye Univ LLC ‘IPO Zaporozhye’, 2008. – 496p.

[5] JV 23.13330.2011 JV. Foundations of buildings and structures, updated edition SNiP 2.02.01-83 *. - Moscow: Russian Ministry of Regional Development, 2011. – 162p.

Inert Compositions For Underground Fire Fighting in Mines

PORTOLA Vyacheslav, GALSANOV Nima

Mining Institute, T.F. Gorbachyov Kemerovo State Technical University, 650000, Kemerovo, Russia

Abstract: The properties of the inert compositions obtained by liquid nitrogen and water co-spraying are shown. The high performance of inert compositions made of gas-borne ice particles to extinguish underground in worked-out mine area is demonstrated. A reduction in coal reactivity after treatment with inert compositions is established.

Keywords: mine; worked-out mine area; spontaneous combustion; underground fire; nitrogen; inert composition.

1.Introduction

Underground fires cause enormous economic damage to mines, threaten the health and life of miners due to the release of toxic gases, combustible gas explosion hazards and coal dust. At Kuzbass coal mines the endogenous fires ignited by spontaneous combustion of coal clusters are the most common accident. The coal cluster formed in the worked-out areas of left pillars and in the places of geological faults in coal beds ignite spontaneously most often. Extinguishing fires occurring in the worked-out mine areas usually lasts a long time because of the fire seat inaccessibility the lack of accurate data on the location of the fire seat. At the time of the fire extinguishing the fire area is isolated from existing mine workings, which may lead to the loss of the whole coal and mining machinery. The rapid suppression of the fire seat allows improving significantly the mine safety and reducing the economic losses resulted from the endogenous fires. The conducted analysis showed that in Kuzbass in the case of immediate extinguishing of the place of spontaneous combustion at the early stage of its development, the average economic damage is reduced by 6.3 times.

The process of underground fire extinguishing differs significantly from fire fighting on the ground. On the surface, the refrigerant supplied to the fire seat usually evaporates into the atmosphere with the combustion products. Therefore, due to the large heat removal from the fire seat the supplied refrigerants (usually water or water solutions) rapidly cool burning substance. Phase transitions of the refrigerant used such as water evaporation take away heat particularly efficiently. The resulting vapor is then condensed in the upper atmosphere, warming the surrounding air.

In underground conditions in the refrigerant heated in the fire seat is distributed in the cluster of coal and rock, transferring its heat to them. The vapor formed from water also condenses in the worked-our space heating it. The result of such suppression is the redistribution of heat produced during the coal combustion and concentrated in a small size fire seat, throughout much more spacious worked-out area in which the refrigerant movement occurred. In such circumstances, the cooling efficiency is determined mainly by the initial temperature of the supplied refrigerant and its specific heat capacity.

For rapid elimination of underground fire seat, the refrigerants allowing absorbing the maximum amount of heat from the heated cluster should be used. For this purpose it is necessary to apply the substances, in which the phase transitions with the heat absorption occur at relatively low temperatures. Taking into consideration that that endogenous fire is considered to be extinguished when the coal temperature drops to 25 ° C, the phase transitions of the supplied refrigerant must occur at lower temperatures. Such refrigerants include liquefied gases such as nitrogen. However, the application of liquid nitrogen in the fire seat may cause an explosion due to its rapid evaporation.

One of the best refrigerants is water, which has the maximum value of the specific heat capacity and greater density. However, when applied in the worked-out area, water flows down the soil of the bed, without impacting on the fire. The compositions which allow treating the rubblized coal clusters are the most efficient for fire extinguishing in the worked-out spaces. Such refrigerants include inert gases, foam [1,2]. However, the inert gas has a slight density and specific heat capacity, that's why it requires a larger amount of gas and a longer time of its supplying to cool the heated coal. The disadvantage of foam is the small radius of its distribution in the worked-out area due to its rapid decay [3,4].

2.Characteristic of the work

The use of ice particles supplied into the stream of inert gas will enable to improve significantly the efficiency of extinguishing the burning coal clusters. This composition produces the spacious treatment of the worked-out area and the created inert atmosphere prevents coal oxidation and heat liberation. The range of transportation of the supplied ice particles in the gas stream will increase significantly compared with drops of liquid, and the cooling process will be improved through the additional removal of heat for heating the ice particles and their transition to the liquid state.

The amount of heat absorbed by the inert composition, consisting of gas and the particles of ice, moving through the heated coal, can be determined from the expression

$$Q = G_G c_G (t_1 - t_0) + G_W c_L (t_T - t_0) + G_W c_W (t_1 - t_T) + G_W r, \qquad (1)$$

where G_G - the consumption of the refrigerant passing through the coal cluster, kg/s; c_G - inert gas specific heat, Joules / (kg K); G_W - the water consumption to form ice particles, kg/s; c_L , c_W - the specific heat of ice particles and water respectively, J / (kg K); t_1 - the temperature of composition passed through the coal cluster, K; t_0 - the temperature of composition supplied to the coal cluster, K; t_T - temperature of transition of ice to the liquid state, K; r - specific heat of phase transition of the liquid to the solid state, Joules/kg.

Analysis of equation (1) shows that the efficiency of the refrigerant used for fire extinguishing, increases with its initial temperature decrease, and also with its density, specific heat and transition phase heat increase. To decrease the initial temperature of the inert composition, the co-spraying of nitrogen and liquid water is done, which leads to the heat exchange between the components and transfer of cryogenic liquid to the gas state, and the water particles to the solid state.

The studies conducted have shown that the properties of the inert composition, consisting of nitrogen and ice particles can be controlled within wide limits by changing the proportion of the initial components and their initial temperature. The ratio of the consumption of cosprayed liquid nitrogen and water to the parameters of the generated inert composition and source components can be described by the equation

$$\frac{G_A}{G_W} = \frac{c_W(t_W - t_T) + r + c_L(t_T - t_C)}{r_G + c_G(t_C - t_G)}, \quad (2)$$

where G_A – is the consumption of liquid nitrogen for the inert composition, kg/s; t_W – the temperature of the water used for the inert composition K; t_C - the temperature of the resulting inert composition, K; t_G – the evaporation temperature of liquid nitrogen, K; r_G – latent heat of liquid nitrogen vaporization, J/kg.

Calculated from the formula (2) the parameters of the inert composition of -195^o C temperature, obtained by mixing of water with different initial temperatures and liquid nitrogen are shown in Table 1.

Table 1: Parameters of the inert composition of -195^o C temperature, obtained by mixing of water and liquid nitrogen

The initial water temperture, ^{o}C	The ratio of nitrogen consumption to water (G_G/G_W)	The mass of the water supplied for 1 kg of nitrogen, kg/kg	The mass ratio of ice particles in the composition, %	Heat capacity of the composition, kJ/(kg·K)
0	3,72	0,269	21,2	1,23
20	4,15	0,24	19,4	1,21
40	4,57	0,22	18,0	1,20
60	5,00	0,20	16,6	1,18
80	5,42	0,18	15,6	1,17
100	5,85	0,171	14,6	1,16

In the case of the inert composition temperature increase the consumption of water required for the gasification of liquid nitrogen increases. Parameters of inert composition having a temperature -100 °C are shown in Table. 2.

Table 2: Parameters of the inert composition of -100^o C temperature, obtained by mixing of water and liquid nitrogen

The initial water temperture, ^{o}C	The ratio of nitrogen consumption to water (G_G/G_W)	The mass of the water supplied for 1 kg of nitrogen, kg/kg	The mass ratio of ice particles in the composition, %	Heat capacity of the composition, kJ/(kg·K)
0	1,820	0,549	35,5	1,39
20	2,105	0,475	32,2	1,35
40	2,398	0,418	29,5	1.32
60	2,680	0,373	27,2	1.30
80	2,960	0,337	25,2	1.28
100	3,250	0,307	23,5	1,26

The data show that the temperature of the refrigerant being increased, the mass ratio of ice particles in the composition and its specific heat capacity also increases. When the temperature of the used water is increasing, the mass ratio of ice par ticles in the composition and their heat capacity decrease. The calculations showed that the inert composition comprising gas-borne ice particles cools the heated coal efficiently compared with the inert gas (nitrogen) or even the foam.

Thus, for 1 kg of coal cooling from 200 ° C to 25 ° C more than 15 m^3 of inert gas with the initial temperature of 15° C is required. The same effect can be achieved using 0.83 m^3 of foam with expansion rate of 200 or 0,32 m^3 of the inert composition consisting of nitrogen and ice particles with the initial temperature of -50° C. Fire extinguishing in underground mines with the inert composition is advisable after the gas survey carried out on the surface [5], to determine the location of the fire seat.

The modification of chemical reactivity of coal after its exposure to the refrigerant influences significantly impact on the efficiency of fighting the endogenous fires in the worked-out spaces. Increasing or maintaining the initial reactivity of the treated cluster promotes the intensive coal oxidation by atmospheric oxygen and the development of spontaneous combustion. Therefore, to avoid recurrence of endogenous fires, it is necessary to evaluate the effect of each refrigerant on the chemical activity of the treated coal.

One of the most important factors affecting the development of spontaneous coal combustion process is the temperature of the cluster[6]. Given that the used inert compositions may significantly reduce the temperature of the treated coal cluster, the study of coal reactivity at different temperatures was conducted. The results of the experiments are shown in Table 3.

Table 3:Modifications of coal reactivity under refrigeration

Coal temperature, ^{0}C	Specific sorption rate, $cm^3/(g\cdot h)$			
	Time from the beginning of sorption, h			
	24	65	148	252
20	0,0625	0,0416	0,0216	0,0109
7	0,0268	0,0173	0,0112	0,0069
3	0,0127	0,0074	0,0043	0,0037
0	0,0079	0,0039	0,0021	0,0017
-5	0,0058	0,0026	0,0015	0,0011
-10	0,0044	0,0021	0,0009	0,0007

Analyzing these data, we can conclude that the cooling effect of inert compounds can significantly reduce the reactivity of coal, which will prevent the recurrence of spontaneous combustion process.

The studies in of the influence of gaseous nitrogen and liquid phase of inert compounds formed after the ice melting and settling of ice particles on the surface of the coal were conducted at the next stage of experiments. The samples of the crushed coal prior to placing it in the sorption vessel were purged with pure nitrogen and nitrogen with the atomized water particles. Simultaneously the untreated coal was studied. The results are shown in Table. 4.

Table 4: Modifications of coal reactivity after treatment

Mode of coal treatment	Specific sorption rate, $cm^3/(g\cdot h)$			
	Time from the beginning of sorption, h			
	24	65	148	252
Untreated	0,0563	0,0324	0,0175	0,0092
Treated with nitrogen with water particles	0,0356	0,0263	0,0131	0,0063
Treated with gaseous nitrogen	0,0598	0,0352	0,0183	0,0105

The studies conducted have shown that the water particles deposited on the surface of coal after the inert composition supplying produce antipyrogenous effect on the coal. Thus, the reactivity of not oxidized coal was decreased by 1.58 times. The coal being oxidized, the antipyrogenous effect of its treatment with water decreases. The treatment only with the gaseous nitrogen resulted in a slight increase in chemical reactivity of the coal. This effect can be explained by removal of oxygen physically adsorbed onto the coal surface by the nitrogen flow. Therefore, after the restoration of air flow the coal begins to absorb the oxygen more intensely.

3.Conclusion

Thus, studies have shown that the combined liquid nitrogen and water or water steam spraying allows obtaining the inert composition, comparable in its cooling effect to the medium expansion foam. The use of the compositions consisting of inert gas-borne ice particles can significantly reduce the time of extinguishing of spontaneous combustion occurring in the worked-out areas of mines. The inert compositions may also be used as antipyrogens to prevent spontaneous combustion of coal, and recurrence of fires after their extinguishing.

4.References

[1] Privalov N.I. Improvement of gas-generatot machines for underground fire fighting / N.I. Privalov, A.A.Kupko, B.S. Lyubarskiy // Coal of Ukraine. – 1991. – № 2. – P. 26 – 27.

[2] Portola V.A. Prospects for the use of the nitrogen for fire and explosion fighting in mines // Bulletin of KuzSTU, 2006. № 3. – P. 57 – 59.

[3] Portola V.A. Parameters of foam method for spontaneous coal combustion fighting // Underground fire localization and extinguishing. – Kemerovo, 1989. – P. 21–27.

[4] Igishev V.G., Portola V.A. Expansion rate of foams, used for localization and extinguishing of endogenous fires. Labor Safety in Industry. – 1983. – № 7. – P. 32.

[5] Portola V.A., Krol G.V. IImplementation of the method of localization of the endogenous fires from the surface. Advances in geotechnical and structural engineering - Proceedings of the Fifth China-Russia Symposium on Underground and Building Engineering of City and Mint. 2008, Qindao, China. – p. 398-400

[6] Portola V.A. Evaluation of some factors' impact on spontaneous coal combustion // FTPRPI. – 1996. – № 3. – P. 61-68.

Modeling Peculiarities of Reinforced Crack of Hydraulic Fracture of Coal Seams for Estimation of Their Permeability

BAEV MIHAIL ALEKSEEVICH

Mining institute, t.f. Gorbachev Kuzbass State Technical University, 650000, Kemerovo, Russia

Abstract: The main differences of coal bed methane from other unconventional hydrocarbon resources are shown. Characteristics features of hydraulic fracture operation of coal seams are analyzed. The factors, affecting the permeability of reinforced crack of hydraulic fracture are marked. And the modeling peculiarities of reinforced crack of hydraulic fracture of coal seams are analyzed.

Keywords: coal bed methane, hydraulic fracturing, proppant, permeability, contact strength.

1.Introduction

The modern world economy is characterized by high energy resources consumption. The development of fuel and energy and metallurgical complex, petrochemical and chemical industry is based on the extensive use of various kinds of mineral resources extracted from the earth. Fuel, energy and technological raw materials oil, natural gas and coal are widely used. The humanity growing needs in these minerals make people increase their extraction continually. Gradual exhaustion or substantial reduction of these reserves in easily accessible deposits has led to complexity and high cost of their production. In this regard, one of the priority tasks is the development of unconventional hydrocarbon resources, which include: heavy oils, oil (tar) sands, coal bed methane, shale gas and oil, gases of tough rocks, gas hydrates and water dissolved gases. Coal bed methane (CBM) has a number of differences from other unconventional resources. Firstly, the high level of its extraction technology allows considering the CBM production possible on a commercial scale and economically useful. This is confirmed by successful projects of coal bed methane reserves development in such countries as USA, Canada, Australia, etc. Secondly, coal bed methane is a high quality and environmentally friendly energy and chemical raw material. Methane concentration in natural gas mixture of coal seams is 80-98%, and the impurities content is minimized. Therefore, there is no need in deep cleaning – in most cases it is sufficient just to dry it. Thirdly, large-scale field methane production as an independent mineral resource will not only meet needs of the coal-mining regions in gas, but also will reduce gas hazard of coal mining in future mines. This, in turn, is one of the conditions for significant increase in coal production.

2.Characteristic of the work

Early methane extraction by wells from the surface (before mining) is done by using the special technology of coal seams gas recovery intensification. In the world practice various methods have been used, such as: seam hydraulic fracturing (SHF), caving, horizontal directional drilling (HDD), pneumo- and hydrodynamic drag (MPE, PHDD and HDT), reactant treatment of wells, the wave action to a seam, helium, nitrogen and carbon dioxide injection into coal seams, plasma impulse excitation (PIE), foam-nitrogen hydraulic fracturing and others. The hydraulic fracturing method is widely used for CBM production. During the hydraulic fracturing process a special technological liquid is pumped under high pressure and high rate into the seam. At one stage of hydraulic fracturing a propping agent (proppant) in the form of natural sand or ceramic granules of a certain size and concentration is added into fracturing liquid. Proppant is distributed in the cracks to prevent their closing after the operation closure. The main purpose of hydraulic fracturing is to create a system of deep penetration into the seam cracks, which links a well with a network of natural origin cracks and increases the drainage area. Such high permeability cracks are pathways and facilitate the flow of gas from the seam depth to the well in order to achieve economically sound production rates. Thus, the wells productivity is associated with cracks geometry and their residual permeability.

One of the main factors in hydraulic fracturing is display of strength and deformation properties of rocks. The difference of coal physical and mechanical properties from other reservoir formations and bedding conditions determines the peculiarities of hydraulic fracturing technology of coal seams and this exposure method effectiveness. The value of Young’s modulus has great influence on geometry of cracks, resulting from hydraulic fracturing [1, 2]. The cracks tend to grow in length and height in rocks with high Young's modulus, being relatively small in width (crack opening). In rocks with low Young's modulus, such as coal, cracks should be relatively wide and short. However, the developed system of natural cracks in coal seams can contribute to high filtration of fracturing liquid deep into the formation; this prevents the cracks growth in width.

Another important factor in cracks formation of fracture is a type of fracture liquid. The technology «slickwater» became widespread for coal seam gas recovery intensification – hydraulic fracturing, using water with a small amount of additives (friction reducers) as a fracturing liquid. As a result of this technology implementation the developed system of cracks is formed; micro seismic studies prove it [2, 3, 4]. Complex geometry of cracks and relatively low disclosure leads to difficulties of their effective proppant attachment. Besides, water has very low sand holding ability, which also reduces the quality of cracks attachment.

Numerous studies show that the main factors affecting the permeability of cracks of hydraulic fracture and proppant packing are: closure pressure of reinforced cracks, temperature, mechanical properties of rocks, proppant type, grain size and surface concentration of proppant, distribution of proppant in a crack, gel remnants, proppant destruction, particle migration, proppant indentation in cracks walls. The influence of all these factors is studied well. However, the research of filtration properties of reinforced cracks of hydraulic fracture of coal seams has a number of features.

Permeability of reinforced cracks of fracture in a coal seam differs from the permeability, determined in accordance with a standard method of measuring the duration of proppants conduction, described in the standards ISO 13503-5 and API RP 19D[5]. The standard method does not fully take into account the peculiarities of physical and mechanical properties of coal and the conditions of coal seams bedding, but information concerning the study of their impact on the filtration ability of reinforced cracks of hydraulic fracture of coal seams is not enough.

In this regard the urgent problem is the task of further investigation of the process of cracks attachment of hydraulic fracture and experiments conduction to measure the permeability of proppant packing in conditions close to the seam conditions. In our case it is necessary to consider the impact of the unique properties of coal seams, which are unconventional reservoirs of methane. What properties of coal should be considered when comparing coal with other rock-reservoirs in the aspect of the analyzed problem? Firstly, these are those properties, which can affect the permeability of proppant bands. These include mechanical properties and parameters which characterize them. In the research [6] we provide objectives that, in aspect of the analyzed problem, the exponent, giving a generalized assessment of rock properties for the process of cracks attachment of hydraulic fracture by granular material, is *contact strength* of a rock. Furthermore, in accordance with the method described in [7], we performed some experiments on coal samples and determined the index value of the contact strength (63.6 mPas). According to this parameter coal significantly differs from sandstone, laboratory samples of which are used in a standard test for measuring the duration of proppants conductivity. Under certain conditions, this difference may have decisive influence on the residual permeability of reinforced cracks of hydraulic fracture. For experimental verification of this impact some studies should be done to investigate filtration properties of reinforced cracks of hydraulic fracture of a coal seam; thus instead of standard laboratory sandstone samples it is encouraged to use the samples, made of coal equivalent material, as to make samples directly from coal, with certain requirements (size, shape) is technically difficult.

From this, it was proposed to produce samples by filling the cement slurry of definite composition in a special mould. This approach is due to several reasons. Firstly, the samples are very convenient to make. The special mould, designed for preparation of standard samples from sandstone, can be used as a mould for filling. After set of mortar and maturing the resulting sample has the required size and shape. Secondly, adjusting accordingly the cement slurry properties (change in its water-cement ratio, input of various additives), it is possible to obtain the necessary cement stone with certain parameters. Thirdly, this material is very affordable and inexpensive.

Let’s analyze in detail the manufacture of cement mortar samples. In order to find the desired composition of the solution let’s proceed from the following considerations. Since contact strength is associated with compressive resistance [7], it is possible to determine what strength cement stone should have to satisfy the requirement in terms of contact strength.

It is easy to see that its compressive resistance should be close to the strength of coal (8-20 mPas for coals of Kuznetsk Basin [8]). From literature[9] we know that connection of strength of cement stone with water cement ratio of the solution, from which it is made and with cement activity, is known (e.g., water-cement ratio law). Thus, water-cement ratio W/C = 0.65 corresponds to compressive resistance of cement stone, prepared from a solution based on Portland cement M400 equal to 20 mPas. Consequently, the cement mortar with such water cement ratio will be basic in our further investigations.

In order to confirm the experimental data of theoretical reasoning in accordance with the method described in[7], some experiments were performed to determine contact strength of cement stone. In experiments cement mortars with water cement ratio W/C = 0.65 were prepared based on Portland cement PC400 GOST 31108-2003 by Topkinsky cement plant. Test solutions were prepared with tap drinking water. Samples-cubes, size 70×70×70 mm, were filled from solutions, as well as samples of cylindrical shape with diameter of 55 mm and 60 mm high. After twenty-four hours samples were taken from the mould, and the remaining time were stored in a room temperature (20 ± 3) °C and with relative humidity of (65 ± 10)%. Samples of the age of 28 days were tested on contact strength. The results of laboratory tests are shown in Table 1.

Table 1：The results of measurements and calculations of cement stone contact strength

№ p/p	Indentor's base area(m^2)	The average failure load(H)	Tests number	Contact strength, (mPas)
1	$7.07 \cdot 10^{-6}$	833.9	22	52.6
2	$14.52 \cdot 10^{-6}$	1226.3	20	

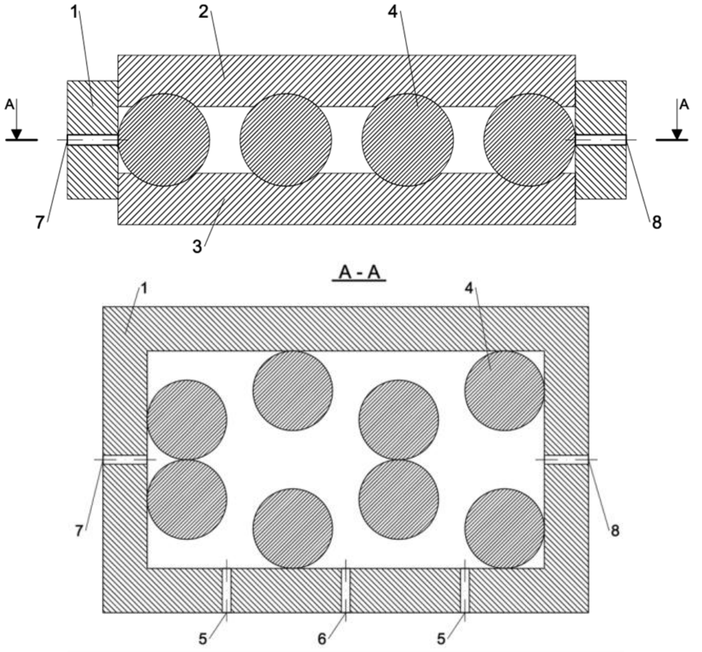


Fig. 1：The model diagram of a reinforced crack of hydraulic fracture of coal seams:
1 - carcass; 2 and 3 - the top and bottom sample of the equivalent material; 4 - proppant grains; 5 - holes for pressure gauges connecting; 6 – a hole for the temperature sensor connecting; 7 - a hole of fluid input; 8 – a hole of fluid output.

The data obtained in the experiments are in good agreement with the reference values of contact strength of cement stone and are close to the values of certain indicators of contact strength of coal. Due to satisfactory results of laboratory tests it was decided to produce samples from the cement mortar for measurements of permeability of reinforced cracks of hydraulic fracture.

In addition to these in the above-mentioned standards it is provided to carry out some measurements with constant surface concentration of proppant. It is necessary to consider the impact of the magnitude of the surface concentration of proppant in modeling of reinforced cracks of hydraulic fracture of coal seams. This will bring the modeling conditions to the real seam conditions. In accordance with the foregoing a diagram of a model of a reinforced crack of hydraulic fracture of coal seams is given on Fig. 1 (assuming the formation of proppant packing in a crack as a partial monolayer).

3.Conclusion

Overall, the results of the researches showed the feasibility and desirability of further study of a reinforced crack of hydraulic fracture conductivity using samples made of an equivalent material. To produce samples it is proposed to fill the cement slurry composition in a certain special mould.

Before making samples for conductivity measurements the control measurement should be done to test contact strength of cement stone on samples specially prepared for this. It will clarify the formulation of an applied mortar. Besides, while modeling of reinforced cracks of hydraulic fracture of coal seams the impact of the magnitude of the surface concentration of proppant must be considered.

4. References

[1] Economides, M.J. Modern Fracturing: Enhancing Natural Gas Production / M.J. Economides, T. Martin. – Energy Tribune Publishing, 2007 – 509 p.

[2] Coal Bed Methane: Principles and Practices / R.E. Rogers, K. Ramurthy, G. Rodvelt, M. Mullen. – Halliburton Co., 2007. – 504 p.

[3] Integrating Fracture Mapping Technologies to Optimize Stimulations in the Barnett Shale / M.K. Fisher, C.A. Wright, B.M. Davidson, A.K. Goodwin, E.O. Fielder, W.S. Buckler, N.P. Steinsberger // Paper SPE 77441. – 2002.

[4] Palisch, T.T. Slickwater Fracturing: Food for Thought / T.T. Palisch, M. Vincent, P.J. Handren // Paper SPE 115766. – 2010.

[5] API RP 19D. Recommended Practice for Measuring the Long-term Conductivity of Proppants. First Edition (ISO 13503-5:2006, Identical) (Includes July 2008 Errata). – 2008.

[6] Baev, M.A. Some results of investigation of reinforced crack of hydraulic fracture of coal seam stability [electronic resource] / / Proceedings of the VI All-Russia. 59th scientific conference with international participation "Young Russia", 22-25 April. 2014, Kemerovo [electronic resource] / «T.F. Gorbachev Kuzbass State Technical University»; Editorial Board.: V.Y. Blumenstein (Ed.). [and others] – Kemerovo, 2014. - 1 electron disc (CD-R).

[7] Baron, L.I. Contact strength of rocks / L.I. Baron, G.L. Glatman. - Moscow: Nedra, 1966. - 227 p.

[8] Physical and technical properties of rocks and coals of Kuznetsk Basin: reference guide / G.G. Shtumpf, Y.A. Ryizhkov, V.A. Shalamanov, A.I. Petrov. – Moscow: Nedra, 1994. – 447 p.

[9] Dvorkin, L.N. Basics of concrete science / L.N. Dvorkin, O.L. Dvorkin. – St. Petersburg: LLC «Stroi-Beton», 2006. – 692 p.

Part V

Mines, underground engineering operation and management

Rare Earth Elements in Kuznetsk Coals: Ability to Excavate and New Functional Materials

CHERKASOVA Tatyana G, CHERKASOVA Elizaveta V, TATARINOVA Elza S, BOBROVNIKOVA Alena A, GORYUNOVA Irina P, MIHAYLENKO Yuliya A, TIHOMIROVA Anastasia V, ISAKOVA Irina V.

Institute of Chemical and Gas Technology Fsbei Hpe, T. F. Gorbachev Kuzbass State Technical University, 650000, Kemerovo, Russia

Abstract: The possibility of excavation of valuable rare earth elements (REE) from coals and excavation of ash dumps on the analysis of their content in Kuzbass is examined and discussed. New functional materials on the bases of REE compounds are presented.

Keywords: Kuznetsk coals, ash and slag waste, rare earth elements, functional materials.

1.Introduction

Rare earth elements (REE) are an essential resource for the creation and development of modern high-tech industries; and in accordance with the requirements of scientific and technological progress the steady growth of production and consumption of rare earth metals is observed in the world. Elements of IIIV-group of the periodic table, scandium, yttrium, lanthanum, and 4f-elements (lanthanides) are used in electronics, instrumentation, mechanical engineering, nuclear engineering, metallurgy, chemical industry. REE market outlets are divided into two segments: the undivided metals used in the manufacture of mish metals (rechargeable batteries), putty powders, glass, catalysts and additives for the petrochemical industry; the individual elements used to prepare luminophores, magnets, ceramic condensers, catalytic filters – converters of exhaust gases, small electronic devices, and for many other purposes. Thus, REE are the future of metals .

In Russia, there are at least 17-20% of REE world reserves (the second place in the world), but extraction of raw materials is only about 2% of the world production; and without the implementation of new projects it will fall below 1.5% in the nearest future. Manufacturing with rare earth metals is less than 1% in Russian. It is obvious that the production of rare earth elements is the most important task of our economy.

Coal, being one of the most exploited natural energy source, now is simply burned, at the best before burning coal is exposed to simple mechanical preparation. The traditional use of coal threatens the ecology of the region: the territory of the Kemerovo region is being overloaded by coal combustion wastes, annually 150-160 million tons of these wastes are produce.

Coal should be considered as a complex raw material, which contains valuable chemical elements. Bottom-ash masses of coals are independent ore deposits located on the surface and they do not require expenses for their extraction. Studies have shown [1-5] that in Kuzbass coals there are a large number of sites containing industrially significant concentration of rare earth metals. Sludge discharges of Kuzbass coal-preparation plants remain unexamined for metals, including rare earth metals [2]. The development of high-selective technologies to extract REE from all possible sources and creation of new functional materials on their basis are important tasks both from economic and environmental point of view.

2.Characteristic of the work

REE are extremely characterized by being combined in natural objects, due to the similarity of their chemical properties because of the proximity of their atomic radii as a result of "lanthanide (4f) compression." Preparation of rare earth metals from ores is produced by means of hydrometallurgy methods, electrolysis and by metallothermic reduction. Extraction of individual REE is produced by ion exchange and extraction.

The main method of coals primary processing and ash and slag waste processing is their development by chemical acidic reagents, in the quality of which mineral acids or organic base-exchange substance in the H^+-form and subsequent processing of leaching solutions are used. Nitric acid was used as the reactant for raw material development. Extraction was done by a well-known butyl phosphate which is highly selective to the rare earth metals. In this case the main macro-impurities (salts of aluminum, calcium, iron) serve as the salting-out agent for rare-earth elements extraction. Extraction by organic amides and sulfoxides is tested. The nitrates and oxides of rare earth metals are used for the direct synthesis of double-complex compounds. The study of their structure by X-ray analysis has established the possibility to get both ionic and polymeric compounds [6-8]. The low-temperature technology of a blended (with oxides of transition metal) nanosized oxide powders production and reversible temperature-sensitive materials production was developed on the based of the investigation of thermal and chemical properties of substances [9, 10].

Heat-sensitive pigments serve as chemical sensors in temperature-sensitive devices, which are used for visual inspection of the thermal regime in various technological processes. The method of temperature indication by means of heat-sensitive substances allows to monitor quickly and accurately and in some cases to regulate the temperature fluctuations over a wide range, there is no need in expensive operations and complex instrumentation; the method allows to measure the temperature of the hard-to-get surfaces of any shape and size, the method is suitable for the direct measurement of the temperature field and distribution of thermal loads. The developed heat-sensitive compositions are characterized by the following properties:

- bright color of pigments and clear transition temperatures;
- the ability to change many times the color at the definite temperature, the range of the temperature change depends on the composition and covers the area from 45 to 220 °C;
- the storage stability of a long period of time and thermal stability under conditions of usage;
- the lack of components, having toxicity and aggression toward the surface of the tested material;
- solubility in organic solvents and indifference to the most commonly used fillers and fixants;
- the durability of the heat-sensitive coating.

In Russia, there is currently no mass production of color temperature indicators, which meets modern requirements of science and technology.

3.Conclusion

Rare earth metals are one of the raw materials of rapidly developing high-tech industry. REE industry is developing towards closed economy, in which the raw material is recycled more than once and used again. Considering the ash and slag, slimes and coals of Kuzbass as a valuable raw material for their complex processing, it is necessary to develop and to improve extraction technologies, in particular, extraction technologies of expensive REE; it will significantly improve the profitability of coal industry by means of rare metals production and production of functional materials based on them. Furthermore, the complicated ecological situation in the Kemerovo region, which is overloaded by waste from coal enterprises, makes the problem of deep processing of raw materials in order to improve the quality of life in the region particularly urgent.

4.References

[1] Nifantov B.F., Potapov V.P., Mitina N.V. Geochemistry and resources assessment of rare earth elements and radioactive elements in Kuznetsk coals. Prospects for processing. Kemerovo. - 2003. - 104p.

[2] Skurskiy M.D. Estimation of rare earth - rare metal – petro gas coal deposits in Kuzbass // Fuel & Energy Complex and Resources of Kuzbass. - 2004. - № 2/15. - P.24-30.

[3] Arbuzov S.I. Geochemistry of rare elements in coals of Central Siberia // Author's abstract of doctor of technical science - Tomsk. - 2005. - 40p.

[4] Salihov V.A. Scientific bases and improving of geological and economic assessment of useful components of coal deposits (on the example of Kuzbass). Kemerovo. Kuzbassvuzizdat, 2008. - 249p.

[5] Arbuzov S.I., Ershov V.V., Potseluev A.A., Rihvanov L.P. Rare elements in Kuzbass coals. Kemerovo. 1999. 248p.

[6] Cherkasova E.V., Peresypkina E.V., Virovets A.V., Podberezskaya N.V., Cherkasova T.G. Octakis (ε-caprolactam-kO) erbium(III) hexaisothiocyanatochromate(III) // Acta Crystallogr. Sect. C: Cryst. Struct. Comm. - 2007. - V.63. - P.m195-m198.

[7] Cherkasova E.V., Virovets A.V., Peresypkina E.V., Podberezskaya N.V., Cherkasova T.G. Structural types of hexa(isothiocyanato) chromate (III) octa (ε-caprolactam) lanthanide (III). Phase transition with reversible twinning // Journal of Structural Chemistry. - 2009. - V.50. - №1. - P.144-155.

[8] Cherkasova E.V., Virovets A.V., Peresypkina E.V., Cherkasova T.G. Synthesis, crystal structure and structural features of the hexa(isothiocyanato) chromate(III) of complexes of lanthanum(III) and neodymium(III) with nicotinic acid // Journal of Inorganic Chemistry. - 2013. - V.58. - №9. - P.1165-1171

[9] Cherkasova T.G., Tatarinova E.S., Kuznetsova O.A., Tryasunov B.G. Reversible thermochromic materials // The Russian Federation Patent 2097714. 1997.

[10] Cherkasova E.V., Cherkasova T.G., Tatarinova E.S. Reversible bimetallic temperature indicator // The Russian Federation Patent 2301974. 2007.

The Main Characteristics of Freight on Hot Streams

EROFEEVA Natalya V.,CHEBOTOVA Irina N.

Mining Institute, Institute of Thermal Power, T.F. Gorbachov Kuzbass State Technical University, 65000 Kemerovo, Russia

Abstract: Authors determined temperature of the extinguished coke by fractional structure. Authors suggested to lower temperature influence from the large heated pieces on a tape at the expense of loads segregation.

Keywords: conveyer belt, coke, temperature, segregation, fraction

1.Introduction

Belt conveyors are applied to transportation of hot freight at coke-chemical plants. Theconveyer belt is the most vulnerable element. The cost of a belt makes from 40 to 70% of cost of the conveyor. The belt fails because of thermal aging and burning by the heated pieces in case of violation of a technological mode. Suppression of coke happens in two stages. One stage is that the heated coke is unloaded in the wagon where suppression by wet way is made. The other is that further coke is unloaded on a ramp where there is an extinguishing of the heated centers. Temperature of the extinguished coke is one of the main of the characteristics necessary for a right choice of conveyor transport on hot traffics of loads.

2.Characteristic of the work

At Cherepovets iron and steel works[1], researches of temperature of coke of wet suppression were conducted. In work it is noted that at wet suppression of 7–10 percent of coke have temperature of 100–160 degrees, the rest – less than 100 degrees Celsius. At the same time in the lump of transported coke of wet suppression pieces (2–5%), surfaces having temperature to 700–800 of degrees Celsius meet. Similar results were received by authors at research of temperature of a surface of coke at the Kemerovo coke-chemical plant (fig. 1, *f*). Thus the maximum temperature of a surface of coke reached 550–600 of degrees Celsius.

The granulometric structure of freight has a great impact on extent of cooling. Smaller fractions making bulk of transported freight are exposed to deeper cooling. Large pieces are exposed to superficial cooling and in the course of further movement from a stage on the conveyor are warmed due to remained internal heat.

Unfortunately, in work [1] the attention to distribution of temperature of a surface of coke on fractional structure isn't focused.

Authors tried to take on the working conveyor at a factory temperature of a surface of coke on fractional structure 0–50 mm; 50–100 mm; 100–150 mm; 150–200 mm and +200 mm (fig .1, *a–e*). Measurements were made in the contactless way by a pyrometer.

The expected temperature of the coke unloaded on the belt conveyor, at confidential probability of 95% is specified in Tab. 1.

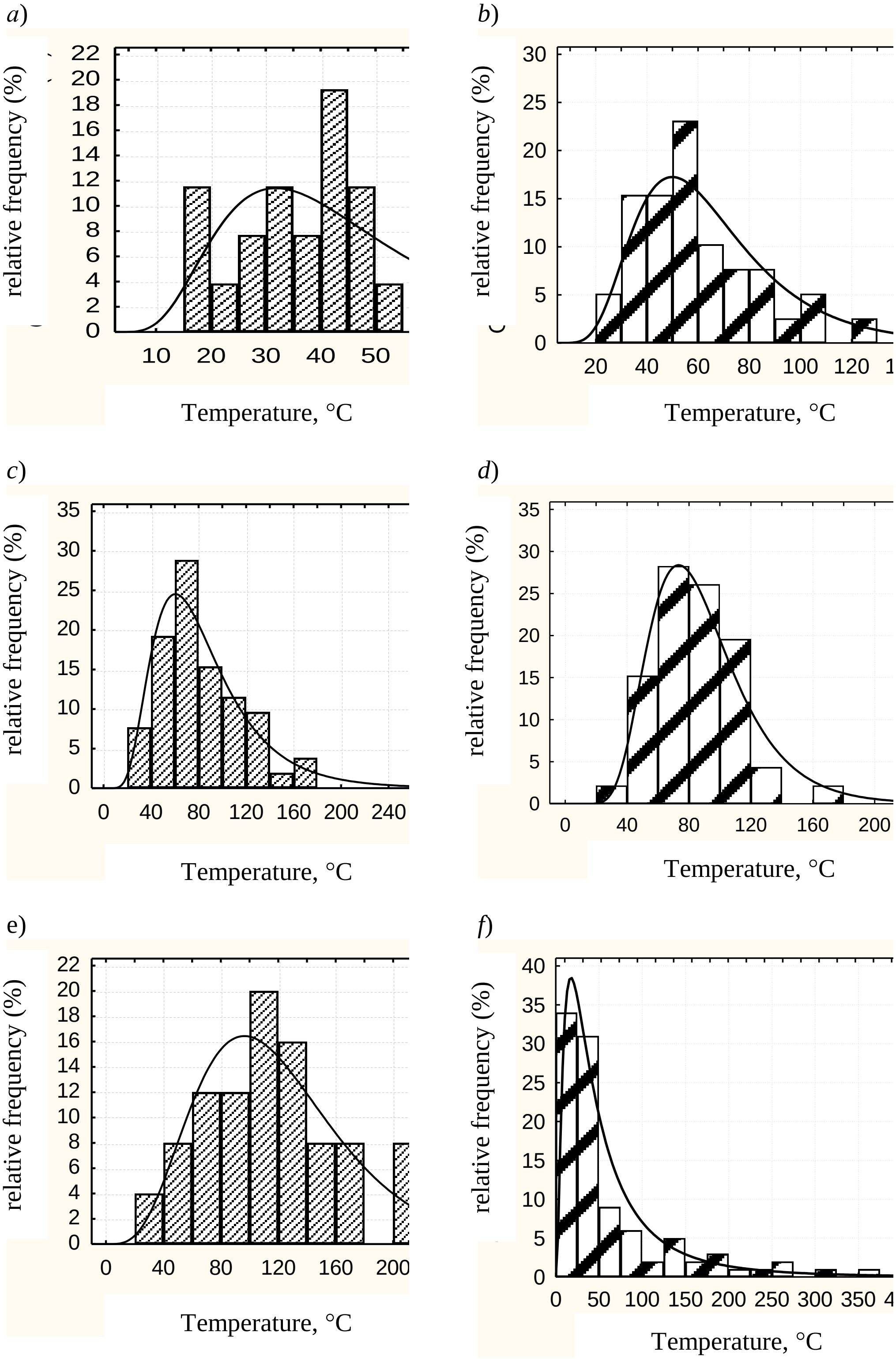


Fig. 1：Histograms of distribution of temperature of a surface of coke of fraction:

a – 0–50 mm; *b* – 50–100 mm; *c* – 100–150 mm; *d* – 150–200 mm; *e* – +200 mm; *f* – 0–300 mm (including pieces of red hot) and the distribution function: *a*, *b*, *c*, *d*, *f* – lognormal; *e* – gamma

Table 1： Coke temperature on fractional structure

Fractions, mm	+50	50–100	100–150	150–200	+200	0–300
Range of temperature, °C	35,2–51,1	55,5–75,2	72,6–98,4	78,6–99,2	98,5–141,1	53,2–90,0

Apparently from Tab. 1, the bulk of transported coke has temperature not exceeding 150°C. But at the same time pieces of a red incandescence meet. Presence of coke of a red incandescence leads to burning of a working lining of the conveyor, and sometimes and a belt framework. In special situations, when unloading on a coke tape to the high maintenance of pieces of a red incandescence (or the centers) there can be a belt ignition [2].

3.Conclusion

As the small fraction of a transported material is heated to 50°C and most to 140°C, it is offered to use small fraction as a layer between larger pieces and a belt, thereby having lowered temperature load of a belt. Such distribution of freight can be received shock and vibration influence on a non-working facing of a loaded branch of the conveyor. In case of hit of the single heated piece on a belt surface the piece as a result of vibration will make micro jumps. During free flight of a piece at the expense of its flow it will start being cooled with an air stream intensively and by that reducing not only the general time of contact with a belt, but also a piece thermolysis to a belt.

4.References

[1] Ananyev N V., Partina T. V., Shreyder E. M., Toletova V. A. About a choice of conveyer belts for transportation of coke of wet suppression //Coke and chemistry. − 1985. − # 2. − p. 21−23.

[2] Makhlis F. A., Chertkov O. S., Borinstein G. A., Ananyev N. V., Mikheyeva I. L., Gavrilina S. A. Heatresistant conveyer belts //Hoisting-and-transport equipment and warehouses. − 1991. − # 4. −p. 20−23.

Study of the Process of the Polymer Flocculants Degradation Used for Coal Processing

EVMENOV Sergey D.[1], EVMENOVA Galina L.[2]

1. Institute of Chemical and Petroleum Technology, T.F. Gorbachev Kuzbass State Technical University, 650000 Kemerovo, Russia
2. Mining Institute, T.F. Gorbachev Kuzbass State Technical University, 650000 Kemerovo, Russia

Abstract: Herein there are the results of study of mechanical and chemical degradation of water-soluble flocculants under ultraviolet and ultrasonic irradiation. Experimentally it was found that the rate and degree of these processes can be evaluated by the change in viscosity of the solutions. The definition of this parameter at the stage of preparation and use of flocculant water solutions let you choose such technological mode when degradation of macromolecules is reducing and eliminating. This ensures maintenance of high flocculant activity while coal preparation.

Keywords: flocculant, mechanical and chemical degradation, viscosity

1.Introduction

Preparation, storage, transportation and practical use of polymer flocculant solutions are often associated with rather intense chemical and mechanical effect, which could lead to degradation, i.e. breaking of the main molecular chain or side groups of the macromolecule substance. Despite the fact that this phenomenon is well known, it is rarely taken into account solving specific technological and practical problems. One of the reasons is the difficulty in determining of the depth of the flow process under production conditions. Therefore, the search for a method that makes such a possibility is very urgent task.

2.Work description

As a model, the diluted solution of polymer flocculants based on polyacrylamide anionic grades Magnaflok 525 and 365 (M 525 and M 365) with a molecular weight (MW) 3×10^6 and 7×10^6, respectively, and cationic Magnaflok 1440 (M 1440) with 1×10^6 MM, are widely used in various industries for wastewater treatment.

The viscosity of the polymer solution η, characterizing internal resistance to the flow, due to the molecular mechanism, and which as per Biki theory of viscosity[1] is associated with a molecular weight of the polymer. If to introduce a concept of a critical molecular weight - $MM_{critical}$ associated with the chain length required for formation of a continuous spatial grid (its nodes are formed by overlaps of macromolecules), then the number of primary, secondary and subsequent links increases significantly at $MM > MM_{critical}$. Resistance to a flow increases, thus the force required to move a macromolecule, interlaced with others, becomes considerably greater compared with the effort required for the motion of a chain, which leads to a viscosity increase. Therefore, in the high molecular weight there is a very strong influence of MM on η , which value becomes proportional to the MM[3,4]. It is easy to assume that the decrease of MM due to degradation should lead to decrease of η.

Preparation of polymer flocculant solutions and their use in the production is characterized by a whole complex of mechanical and chemical effects on macromolecules under the influence of various factors, but the most typical are the chemical and mechanical degradations.

It is known that chemical degradation is possible not only due to strong oxidants introduced into solution, but also by energy of ultraviolet radiation sufficient to break chemical bonds with formation of free radicals, which are usually quick to react with present oxygen[2]. In this case, one of the main factors affecting the photo-degradation process is the number of quantum of the absorbed radiation; and degradation of the flocculant solutions can be explored without fear of the side effects due to trace impurities introduced to the solution with oxidizing agents. Therefore, during the experiment an irradiation treatment of flocculant solutions was carried out by UV rays of mercury-quartz lamp, provided stable reception of the luminous flux of 4200 lumens.

Mechanical degradation generally occurs due to the fact that the applied voltage exceeds the strength of chemical bonds between the atoms of the main chain. The possibility of this process is defined by the ratio of the sum of energies of intermolecular interactions ΣE_{ms} and energy of chemical bonds E_{xc} of the main chain. If $\Sigma E_{ms} > E_{xc}$, chemical bonds will be destructed first. However, the diluted solutions of polymers are characterized by the ratio $\Sigma E_{мс} < E_{xc}$, where macromolecules are more likely sliding along each other, but not breaking [3]. At the same time, the forces generated by stirring of solutions in mixes of various types, their transportation through pipelines and extruding through filters lead to the creation of solutions with great velocity of shear, and that is accompanied by very intensive movement of molecules of the solvent relatively to the less mobile macromolecules, leading to the break of chemical bonds.

Mechanical destruction of solutions was examined by ultrasound of 15 kHz frequency and 55 W/sm^2 intensity, because out of all kinds of mechanical impact the ultrasonic radiation (UR) is the best one for the quantifiable description, and its intensity and frequency are much easier to measure than the shear stress, for example, in the mixing process. [2]

The degree of destruction was estimated by the change in viscosity of the solutions using a Höppler reo-viscometer (made in Germany), which operates on the principle of gravity (motion) of the calibrated on diameter ball under the applied load in a cylindrical measuring vessel filled with liquid. The motion of the ball is from weights having share zone created during measurements.

Magnaflokov solutions M 365, M 525 and M 1440 of 0.1 % (w) concentration were studied. The results of the study are presented on Figures 1, 2 and Table 1. Changes in viscosity were evaluated by the value Δη (%) using the formula as follows:

$$\Delta\eta = \frac{\eta_0 - \eta_i}{\eta_0} \cdot 100,$$

where η_0 – initial viscosity of the solution before irradiation, сПз (centipoise); η_i – viscosity of the solutionость after irradiation, centipoise.

Fig. 1 shows the dependence of viscosity of η polymer flocculants from time of UV irradiation, which is directly dependent on the number of photons absorbed radiation.

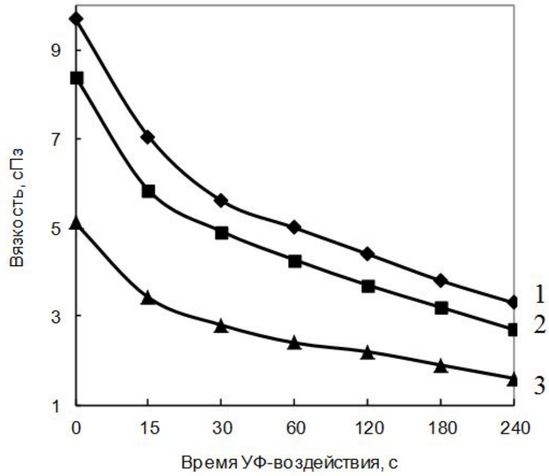


Fig.1: The Influence of the UV Irradiation Time on the Polymer Solutions:
1 – M365; 2 – M525; 3 – M1440

This dependence for all materials is practically the same, but the numerical values of viscosity change Δη (Table 1) are essentially depend on the MM of the original polymer, which determines the initial solution viscosity η_0 at t = 0. Obviously, that the viscosity drops intensively during the first 60 seconds of irradiation, for example, 365 M Δη is 51.3%. Later, within the experimentally studied length of time the rate of change of viscosity is significantly reduced and becomes approximately constant. The maximum value of Δη at t = 240 sec. is observed for M 365 (66.7%), the minimum for M – 1440 (61.7 %).

Table 1: The Change of the Viscosity of the Polymer Flocculant Solutions Δη at Degradation

Type of Irradiation	Grade of Flocculant	Irradiation Exposure Time, sec.							
		0	15	30	60	120	180	240	360
UV	M365	0	40.9	45.7	51.3	59.0	–	66.7	–
	M525	0	31.7	36.6	43.9	51.2	–	64.6	–
	M1440	0	23.4	38.3	44.7	48.9	–	61.7	–
US	M365	0	–	–	42.2	54.2	59.5	60.7	72.1
	M525	0	–	–	21.6	31.3	42.9	46.2	61.0
	M1440	0	–-	–	34.0	42.6	48.9	55.3	59.6

It should be noted that at different values of the initial viscosity of the polymer solutions with increase of the UV exposure time the leveling of value η happens, and after 60 sec. They become rather close. Another interesting feature was revealed i.e. the Magnaflokov solutions 365, 525 and 1440 reduced their initial viscosity to a 3^d to the same value during a maximum period of exposure (t = 240 sec.), regardless of their molecular weight. Moreover, the higher the molecular weight of polymer, the more actively destruction process goes, that should be considered at developing and implementing of the technology for dissolving of polymers.

Mechanical effects on the flocculant solutions by ultrasound cause mechanical degradation of polymers, that is also which is characterized by a decrease in viscosity (Fig. 2).

Besides, there are some peculiarities as more uniform in time decrease of this parameter for all flocculants except for M

365, for which, for example, after 60 seconds of ultrasonic exposure $\Delta\eta$ was 42.2% (the rest – 1.634%), Table. 1.

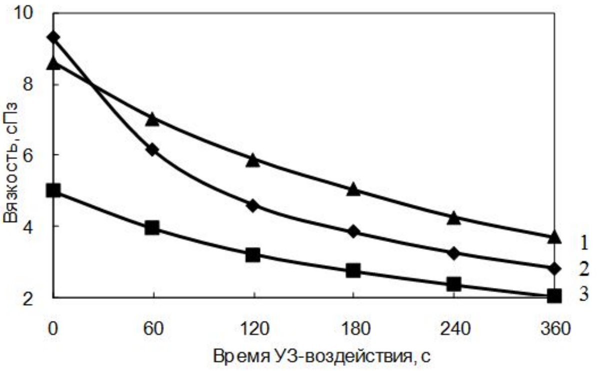


Fig. 2: The influence of the US Exposure on the Viscosity of the Polymer Solutions:
1 – M365;2 – M525; 3 – M1440

3.Conclusions

The experimental results show that:

– the viscosity of the polymer flocculant solutions is fairly reliable, though indirect characteristic, with the help of which you can evaluate the rate and extent of degradation processes;

– the determination of viscosity allows adjusting the depth of degradation process at preparing solutions by selection of the process parameters that allow either eliminate or substantially reduce degradation of macromolecules in order to maintain a high activity of the flocculants at coal preparation.

4.References:

[1] Midlman S. Polymer flow. - M.: Mir, 1971. – 259 p.

[2] Grassie N., Scott G.. Polymer Degradation and Stabilization. Translation from English – M.: Mir, 1988. – 446 p.

[3] Tugov I.I., Kostyrkina G.I. Physics and Chemistry of Polymers. – M., Khimiya, 1989 . – 432 p.

Safety of Mining Engineering Buildings and Facilities Under Fem Analysis and Catastrophe Theory

Pershin Vladimir Viktorovich, Nazarov Dmitriy Ivanovich

Department of Construction of Underground Facilities and Mines, Mining Institute, T. F. Gorbachev Kuzbas State Technical University, City Kemerovo, 650000, Russia

Abstract: The analysis of bearing structures of mining engineering buildings is conducted, the relationship between geometrically nonlinear FEM analysis and catastrophe theory in the dynamic fracture of facilities under static loading is shown.

Keywords: FEM, geometrically nonlinear FEM analysis, structure fracture, bifurcation of structure joints, catastrophe theory.

1.Introduction

Current economic conditions make demand on the construction of mining engineering buildings and facilities designed with the use of FEM analysis program, Russian - Lira, ScadOffice, foreign - ANSYS, Nastran, etc. Current Russian legislation - ФЗ-384 “Regulations on safety of buildings and facilities” requires to follow Standardized Regulations 16.13330.2011 “Steel Construction (updated edition of Construction Rules and Regulations II-23-81*)” designing steel bearing structures of buildings and facilities of the coal mining industry enterprises.

According to the given regulation it is prescribed to perform the structural analysis taking into account the geometric nonlinearity. However, the necessity of considering the bifurcations in the geometrically nonlinear analysis of building structures is not regulated.

2.Work characteristic

The problem of consideration of bifurcations in FEM analysis was formulated in the papers [1, 2, 3] in the form of test problems, one of them is shown in Fig. 1, the base of the problem is linear elastic rod, i.e. □ *l*=*N*□ *l*/EA, where □ *l* is - rod extension, *N* - longitudinal force in the rod, *l* - length of the rod, EA - the longitudinal stiffness of the rod. The deformation scheme of this structure is shown in Fig. 2.

The example given and test problems [1] show that under the bifurcation the finite element method, solving problems in a static setting, cannot be applied, and the bifurcation leads to the destruction of structures.

Fig. 3, 4 presents schemes and graphs for the analysis of bifurcations.

For the analysis of brittle (dynamic) fracture under static load, we consider the structure shown in Fig. 5.

In accordance with the classical theory of catastrophes [4], an example of the codimension 1 bifurcation is shown in Fig. 6.

However, when modeling the bifurcation taking into consideration the dynamic parameters of the system, namely, for the paired ВСт3кп steel corner №10, 150 cm long with a deviation of 7 cm, we obtain the critical force of ≈ 500 kilogram-force, deflection before bifurcation - 3.172 cm, after bifurcation (point D in Fig. 6) corresponding to static load ≈ 4500 kilogram-force. The impact energy under bifurcation ≈ 100 joule/cm^2, which exceeds the impact energy absorbed by the steel ≈ 100 joule/cm^2.

The more comprehensive energy analysis of the singleton bifurcation may show that the static equilibrium points of the system (Newtonian mechanics), the minimum point of the system energy (Chaplygin mechanics) and the variation point of the system energy (Lagrangian mechanics) - do not match, which indirectly indicates the nonholonomic properties of the system.

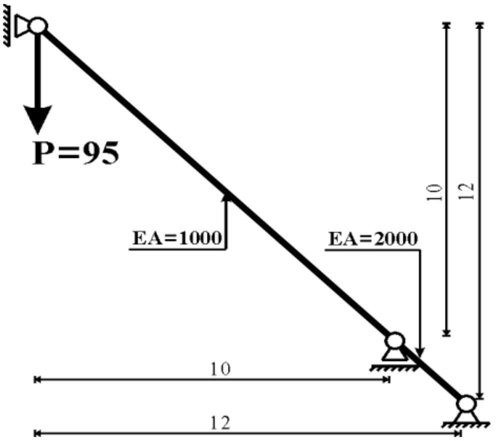


Fig. 1: Scheme of the structure

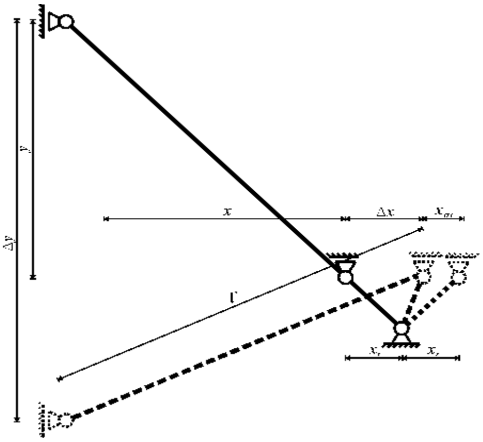


Fig. 2:Deformed scheme

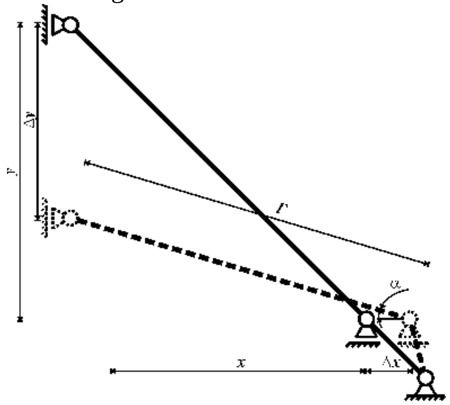


Fig. 3:Scheme of interaction between left and right elements

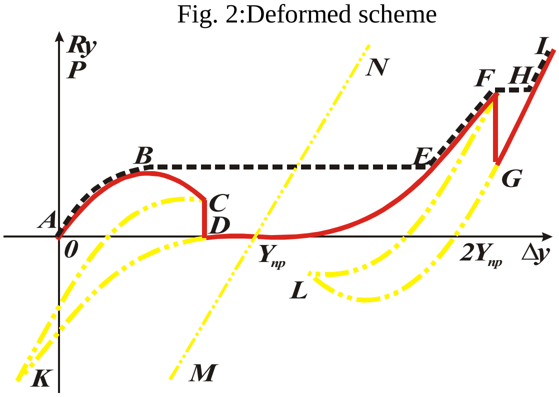


Fig. 4:Determination of critical force for the right element position

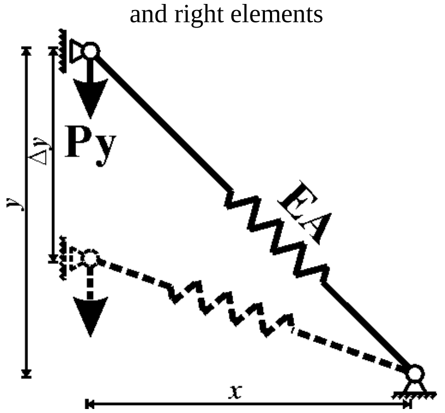


Fig. 5: Scheme of the element bi-furcation model

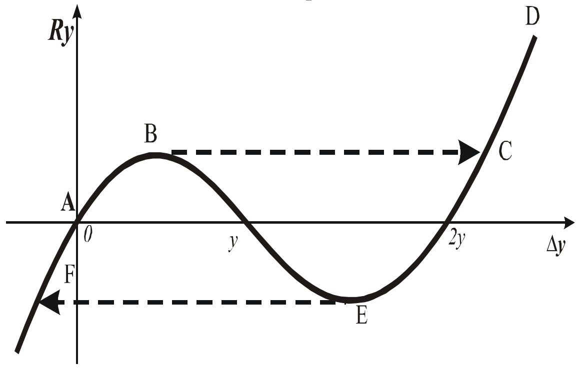


Fig. 6: Position bifurcation according to catastrophe theory

Graph of external Py force energy changes and the deformation energy is shown in Fig. 7.

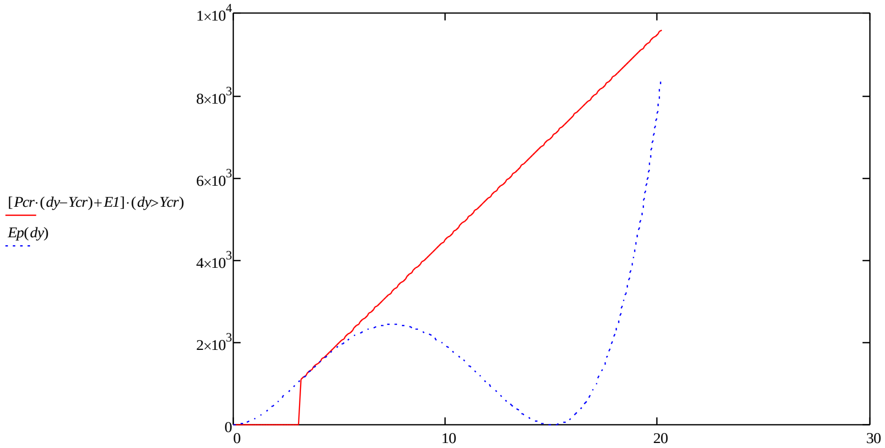


Fig. 7. Graph of external force energy changes and the deformation energy

The building in city Prokopyevsk of Kemerovo region surveyed after its fracture in 2011 by experts of Kuzbas State Technical University and OOO «Kemerovostroyproekt» (LLC "Kemerovo Construction Design") may serve as an example of the structure failure provoked by bifurcation of joints. The aim was to develop guidelines and working documents for the earliest possible repair of the building. However, this work occurred to be significant for science, due to the specific destruction of structures.

The industrial-purpose building, single-storey, single span, of 18x30m size and - 8.34m height (see Fig.8).

The building was constructed in 2009 according to the 08/10/2007 design made by the specialized licensed design organization.

Fig. 8：The general view of the building

Climatic conditions are：

— the normative wind pressure - 30 kg/m2 (II district);

— the designed value of the snow cover weight - 240 kg/m2 (IV district);

— the designed temperature of the coldest five days - 39^{o} C;

—seismic area - 7B.

Exterior walls are from sandwich panels.

Roof bearing structures are 18m span gabled metal girders.

Columns - metal.

Foundations - piles with monolithic grillage.

Runs along the upper girders are from rolled profiles.

Chord and column braces are of continuous-type bent steel square profiles.

Roofing is soft of rolled materials.

Roof insulation is mineral wool.

During the examination the causes of fracture of bearing structures were studied. The fracture of the building occurred after one year of use, the building was designed by a specialized organization, with the endorsement of the state examination with a permanent technical supervision of construction, manufacturer of structures designs being a specialized factory.

The regulatory snow load wasn’t exceeded during the operation period (according to the Prokopyevsk meteorological station). Dynamic effects, including those of seismic character were not observed either.

However, the deformation of bearing girders, the scheme of which is shown in Fig. 9, the destruction of four chord elements, without the roof collapse (Fig. 10-11, the feature of which is brittle fracture of elements 6-7 (see Fig. 9) of four girders have occurred.

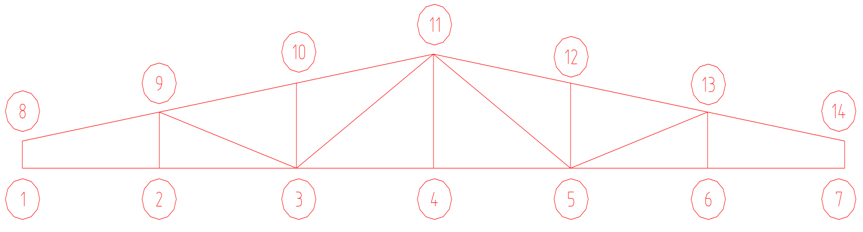


Fig. 9: Geometrical scheme of fractured girder

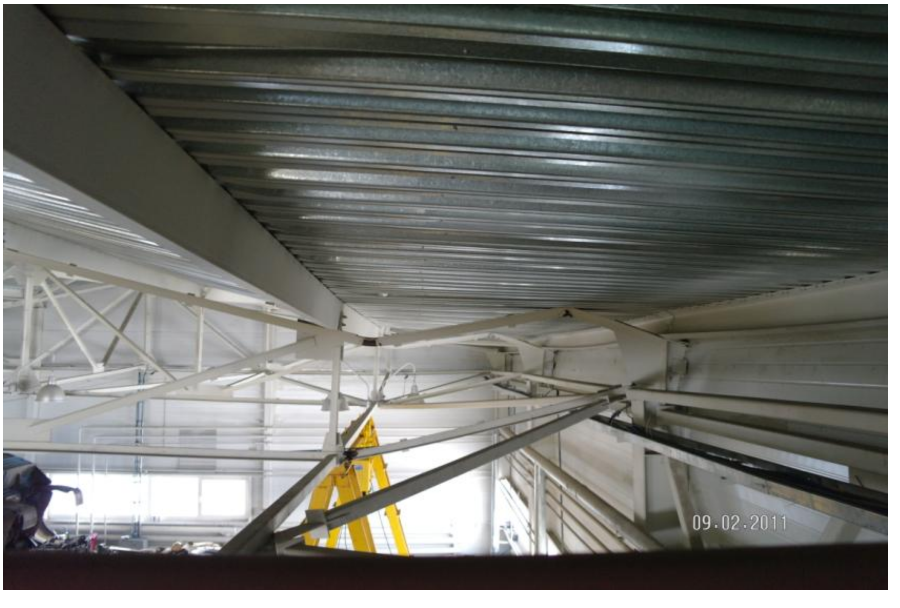


Fig. 10: Girder collapse character

Fig. 11: Brittle fracture of lower chord

Due to the uniqueness of the fracture, as well as to exclude other causes of the structure fractures, a thorough inspection was made. The survey resulted in identification of the nearly two dozens of defects according to Standardized Regulations 13-102-2003 "Rules of surveying the bearing structures of buildings and facilities," but all marked defects were not the causes of the brittle fracture of the lower chord.

Despite the sole cause of the dynamic effects – bifurcation of structure elements, a thorough examination and measurements were performed to exclude other causes of structural collapse, as well as to develop the most optimal method of structure enforcement.

This example clearly shows the danger of non-use of catastrophe theory in FEM analysis of bearing structures of buildings.

3.Conclusion

The analysis conducted and the previously mentioned test problems [1] demonstrate that the FEM analysis, solving problems in a static setting is not applicable under bifurcation.

The task of taking into consideration the bifurcation of joints of rods is not just relevant, but critical. Using catastrophe theory applied to the FEM analysis of limit state of bearing structures of mining engineering buildings and facilities will provide, in our view, further development of science (at least – complete it with the real examples of the general theory of bifurcations[4]) and increase the safety of mining industry buildings and facilities.

4.References

[1] Nazarov D.I. Some features o geometrically nonlinear problems // Automation and computerization in construction: collection of research papers of I International scientific conference. – Tula: Tula State University. 2000. – P. 96-99.

[2] Nazarov D.I. About “fidelity” of structural analysis by means of finite element method // CAD systems and graphics. – 2000. – № 7. – P. 53–59.

[3] Nazarov D.I. Catastrophe theory in the problems of condition analysis of mining engineering buildings and facilities // Bulletin of Kuzbass State Technical University – № 2. – 2010 – P. 80-81.

[4] Seydel Rüdiger. Practical bifurcation and stability analysis / Berlin: Springer, 2010.

Physical Basis of the Controlled Electrochemical Treatment of Soils from Oil Products

PROSTOV Sergey M., GUCAL Maxim B., SHABANOV Evgeniy F.

Mining Institute, T.F. Gorbachev Kuzbass State Technical University, 650000, Kemerovo, Russia,

Abstract: There are the main sources of pollution of soils Kuzbass are presented. The ranges of electrical resistivity of solutions containing oil and contaminated soil, depending on the degree of contamination are presented

Keywords: specific electric resistivity, electrochemical treatment, control, oil products.

1.Introduction

Currently the problem of soil clearing from various pollutants of industrial origin becoming increasingly urgent. The most contaminated soils are in populated areas near highways, on the territories of the industrial facilities, both operation and abandon. Just a serious problem is the contamination of soil by radioactive elements as a result of the nuclear industry. Also rather serious problem is contaminating of soils as a result of activity of atom industry. As ecotoxicants can be heavy metals, oil and oil products, cyanides, and organic chlorine compounds. Concentration of toxicants can exceed maximum allowable concentration (MAC) in hundred times.

In Kemerovo region general environmental conditions are defined by development industry and the predominance of the urban population. Industrial production is the leading sector of the region economy with a predominance of the following industries in the regional economy: ferrous metallurgy, coal and chemical industry. In the region there is a great number of boilers operating on solid fuels i.e. coal. Products of coal combustion (slag and ash) are stored and kept on the ground surface what leads to contamination by the chemical elements contained in the ash and slag.

There are 331 operating wastewater treatment facilities in the region, including 164 industrial wastewater treatment facilities, 20 storm-water runoff treatment facilities and 147 household sewage and mixed one with sewage. The capacity of the treatment facilities, after which the wastewater is discharged into surface water bodies is over 760 million cubic meters.

It seems that a problem of development of the controlled methods for purification of soil pollutants without prior removal of the contaminated soil is urgent. Monitoring of the property changes of the treated area allows timely adjustments to operating practices and optimization of costs. In particular, the intensity of the electrochemical treatment is controlled by electric current density, and in case of combination of the electrochemical process with biological one, they control temperature of the processing zone. To increase the effectiveness of the treatment methods it's necessary to develop efficient and not so efficient ways of geo-control providing definition of the geometrical parameters and substantiation of the optimal treatment modes for a zone under treatment. To meet those challenges to the greatest extent it's required to develop geo-electric methods of control, based on the parameters of the electric fields due to the physical properties and composition of soils.

2.Work description

The Kuzbass coal industry presents 62 underground mines, 57 open pits and 49 preparation plants and units. Their production capacity is 245 million tons of coal per year in coal mining and 166 million tons in processing.

The main sources of soil contamination at the mining and processing sites in the Kuzbass region are:

- Facilities for industrial wastewater and sewage (groundwater filters);
- Fuel stations;
- Boilers and power plants;
- Dry and slurry dumps;
- Sludge pits of preparation plants.

The number of objects, the sources of soil contamination, in one of the largest coal producers of OJSC UK'Kuzbassrazrezu gol' are shown in Table 1.

Table 1: Sources of pollution in the OJSC UK'Kuzbassrazrezugol'

Open pit	Oil and lubricant warehou-se	Bo il-er	Prepar-ation	Groundwater-filters		Slud -ge pits	Slurry pits	Dry dum -ped
			plants	Comp-lexes				
Kedrovskiy	1	1	1	2	3	2	1	4
Mokhovskiy	3	3	-	2	1	2	2	7
Bachatskiy	2	1	2	1	-	2	-	4
Krasnobrodskiy	3	5	1	2	2	2	-	9
Taldinskiy	3	3	-	1	1	1	1	11
Kaltanskiy	2	2	-	-	5	2	-	7
OJSC UK'Kuzbassr-azrezugol' OAO	14	15	4	8	12	11	4	42

The electrochemical method is a potentially promising treatment method out of the existing methods of cleaning soil from industrial pollutants (Fig.1). A distinctive feature of this method that it can be used for cleaning soils with low filtration capacity on-situ, without a notch and moving of soil.

The physical basis of this method is the electro osmotic movement of eco-toxicants under the Helmholtz-Smoluchowski equation:

$$\overline{V} = -\frac{\varepsilon\varsigma}{\mu} grad\varphi \qquad (1)$$

where $\overline{V}$ - average capillary flow rate as per the cross section, m/s; ε - total dialectical permeability, F/m; μ - dynamic coefficient of viscosity, Pa·s; ς - electric kinetic potential, V; φ - potential of outer electric field, V.

On the basis of the dimensional analysis, the dependence of the effective rate for the module $V_{эф}$ (rate of flow) was obtained:

$$V_{ЩТ} = C\sigma_0 \frac{m^2 R}{\mu} E = \frac{m\varsigma\varepsilon}{\mu} E = K_щ E, \qquad (2)$$

where C - constant; σ_0 - specific volume of charge density of the ions of diffuse layer, C/m^3; m – soil porosity; R – hydraulic radius of pores, m; $K_Э$ - coefficient of electro osmotic activity, m^2/(V·s); E – field density, V/m.

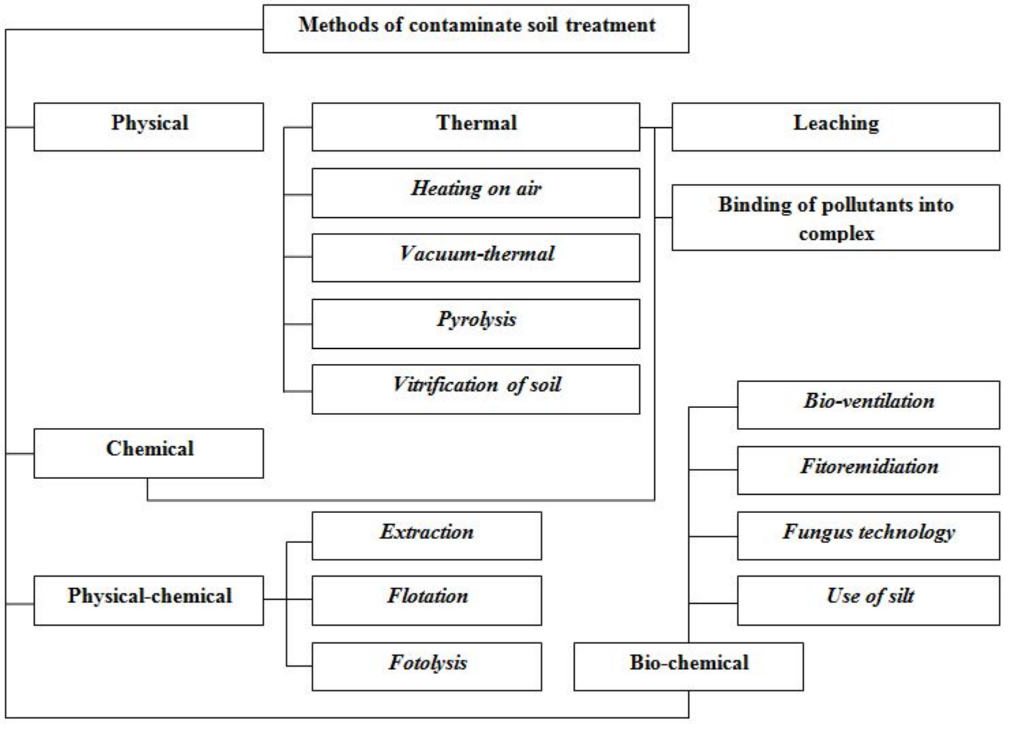


Fig. 1:Classification of contaminated soil treatment methods

During cleaning the pollutants move along the electric field lines, the structure of which is determined by the location of the electrodes; the rate of pollutants' movement depends on the field intensity, allowing monitoring the cleaning process and managing it. Initial concentrations of eco-toxicants can be reduced from 10-50 mg / kg to 1.10 mg / kg, which is well within the existing norms.

The main test parameters of the geo-electric method are: specific electrical resistivity (SER), dielectric and magnetic permeability, electric strength, potentials of steady and unsteady natural electric fields.

Effective SER of the moisture saturated rock, which is a three-phase medium, is descried by the empirical dependence [1]:

$$\rho_Й = \frac{\alpha \kappa_O}{m^{\beta} W^{\gamma}} \rho_Б, \qquad (3)$$

where $\rho_Й$ – porosity (pore porosity); W– moisture saturation coefficient of pores and cracks; $\rho_Б$ – SER of the solution filling the pore space, Ω·m; κ_O, α , β , γ – empirical parameters depended on the structural and textural features of the studied soils (rocks); κ_O – parameter that takes into account a surface conductivity of clay micro-layer on the pore surface; α – parameter depending on the type of geological deposits; β – parameter defined by structure of pore structure (mainly by sinuous channels); γ – parameter depending on wettability of the pore surface by solution.

Table 2: Predictive values of structural parameters β и γ

Type of soil		Parameter β								
		Sand clay ($\overline{m}$ = 0,314; $\overline{W}$ = 0,187)			Clay loam ($\overline{m}$ = 0,296; $\overline{W}$ = 0,227)			Clay ($\overline{m}$ = 0,324; $\overline{W}$ = 0,189)		
Parameter γ		1,8	2,2	2,6	1,8	2,2	2,6	1,8	2,2	2,6
$\left(\frac{\rho_Й}{\rho_Б}\right)$	10,0	0,59	1,15	1,72	0,30	0,79	1,27	0,62	1,21	1,80
	5,0	1,18	1,74	2,32	0,87	1,36	1,84	1,23	1,82	2,41
	2,0	1,96	2,51	3,13	1,62	2,11	2,60	2,05	2,64	3,23
	1,5	2,20	2,77	3,34	1,69	2,35	2,83	2,30	2,89	3,84
	1,2	2,40	2,95	3,53	2,04	2,53	3,02	2,50	3,09	4,46

Table 2 presents estimated values of the parameters β and γ, obtained due to the use of the true range $\rho_Й/\rho_Б$ at geo-control of the wetted rocks, as well as average values of physical and technical parameters $\overline{m}$ and $\overline{W}$ for clay ground of Kuzbass, given in the article [2], for the major types of clay-bearing soils.

For further analysis of the process of electrochemical treatment of the contaminated soils the information regarding electro physical and electrochemical properties of natural water solutions and liquids containing contaminants saturated soils is required. An experimental study of the electrical properties of electrolyte solutions containing oil, and measurement at a constant and alternating electric current is carried out.

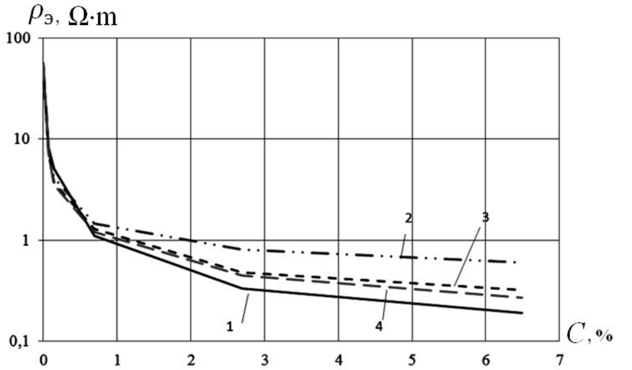
Fig.2 presents measurements of specific electrical resistance (SER) $\rho_щ$ of NaCl solution depending on the concentration of the salt in the solution, and the AC frequency; and Fig. 3 presents similar SER $\rho_м$ dependences of motor oil and gasoline. From these data, it' clear that that all oil products are electrically very contrast because their SER 3 times higher, at least, than resistivity of natural water solutions.

Since the formation of stable, homogeneous oil-water slurry is very difficult, for further theoretical estimation, a logarithmic dependence of the average for the two-component medium, allowing calculation of the required resistivity with higher accuracy[3] was used:

$$\lg \rho_б = V_м \lg \rho_Н + V_щ \lg \rho_щ, \quad (4)$$

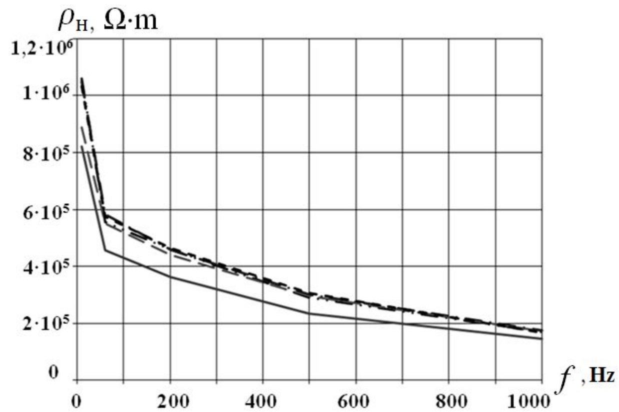
where $\rho_б$, $\rho_Н$, $\rho_щ$ - SER accordingly weighted, oil and electrolyte; $V_м$, $V_щ$ – volume of oil and the electrolyte in the solution, respectively.

Substituting the data from Fig. 2, 3 into equation (4), the dependencies on the average weighted values $\rho_б$ of the oil content $V_м / V_щ$ for DC (Fig. 4) and AC (Fig. 5) currents were obtained.



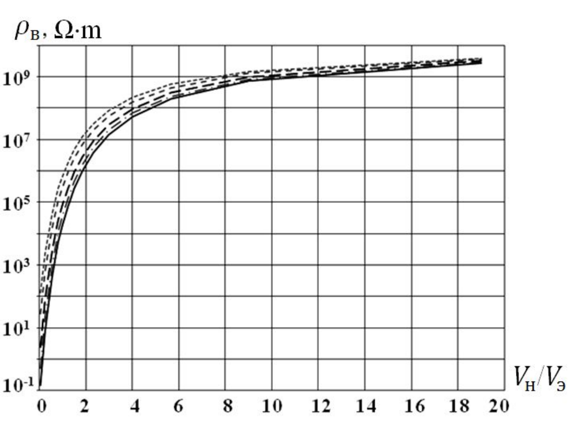
1 –direct current (DC);2 – alternating current (AC), f=10 Hz; 3 – 200 Hz;4 - 1000 Hz

Fig. 2. Dependence of SER solution $\rho_{щ}$ from salt C concentration in solution



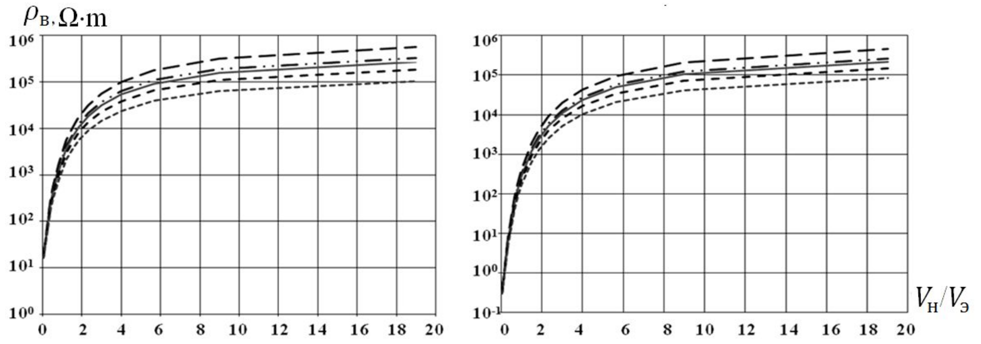
.... - G-Energy F Synth 0W-40; ▬ ▬ - Mobil Synt S 5W-40; ▬ ▬ ▬ - Shell Helix Ultra (worked out); ▬ . . - Shell Helix Ultra; ▬▬▬ - gasoline Ai-92

Fig. 3: Dependence of SER $\rho_{м}$ of motor oil from frequency of alternative current



▬▬▬- saturated solution; ▬ . ▬- salt concentration in solution C = 50 g/l; ▬ ▬- C = 10 g/l; ▬ ▬ ▬ - C = 0,5 g/l; ....- C = 0,1 g/l

Fig. 4: Dependence of the average weighted values $\rho_{б}$ from relatively to the content of oil products on DC



(a) (b)

— — - f= 10 Hzц; — . . - 60 Hz; ——— - 200Hz; – – – - 500Hz; .... - 1000 Hz

Fig. 5: SER average weighted depending on the frequency of the alternating current and salt concentration in electrolyte C = 0,5 g/l (a); 50 g/l (b)

To implement the theoretical dependence (3) following assumptions were made. According to studies of V.N. Kobranovoy [4] a parameter value α can be taken as 1 for sand and clay deposits of the same type. Parameter κ_O of the surface conductivity can also assumed as 1, because if contaminated by oil products is likely to form oil film of little-conductivity on the surface of the solid particles of the soil.

Given the ranges of the structural parameters β and γ shown in Table. 2, the dependence of the efficient SER changes of the main clay of the Quaternary deposits in Kuzbass were calculated. They are partially shown on Fig. 6.

These given dependences allowed forming a database for interpretation of the experimental sounding if the relation $V_м / V_щ$ changes at monitoring as per the value $\rho_Й$.

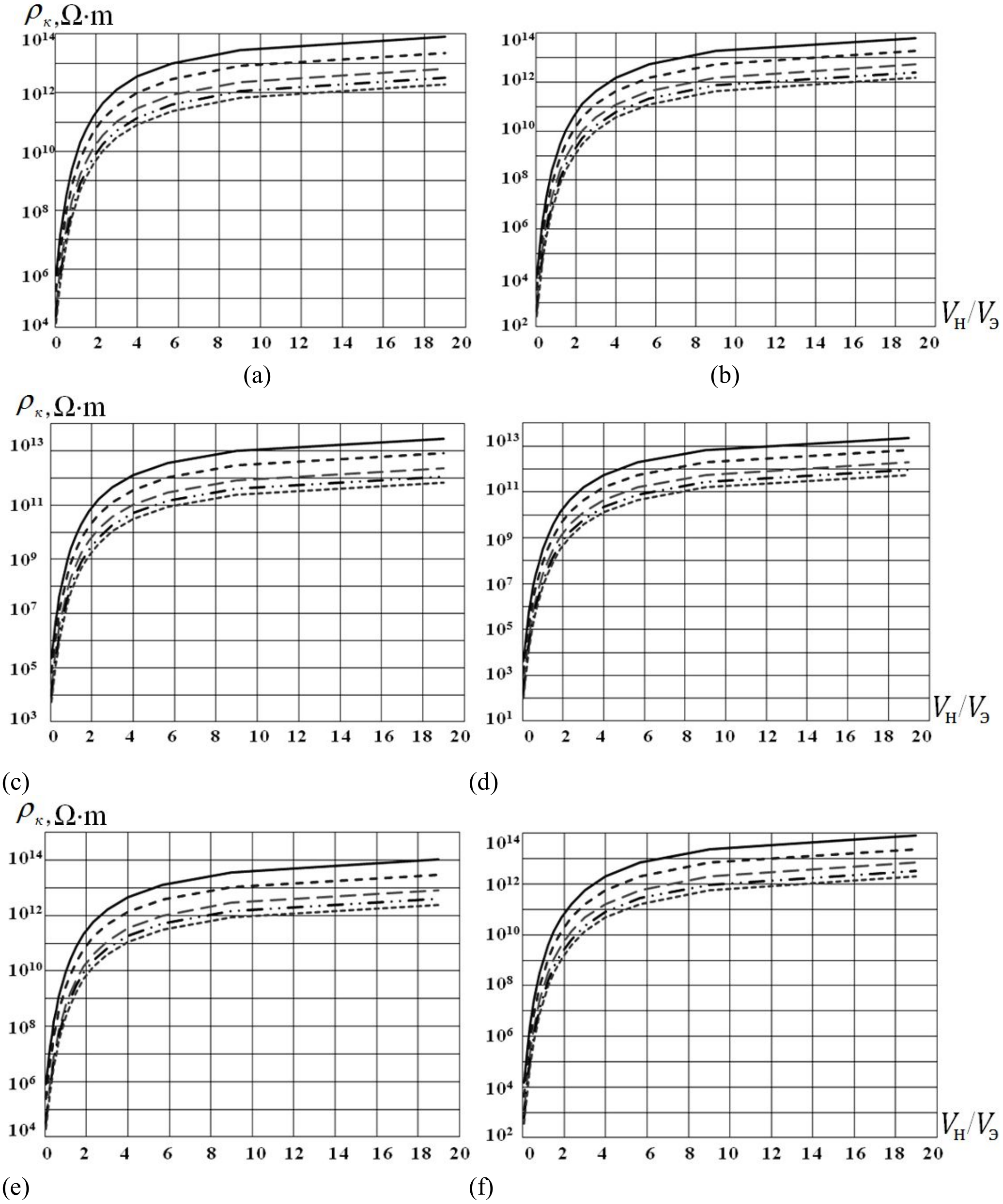
3.Conclusion

The analysis of the results led to the following conclusions.

1. SER of natural liquids and oily pollutants saturating soil, are electrically contrasting, and several times different in the direction of the contaminant, which allows to determine sufficiently the geometrical parameters of the zone of the contaminated soil and the degree of its contamination.

2. For the diagnosis of geometrical parameters of the contaminated areas and control over spreading of the eco-toxicant, it’s expedient to develop methods of electrical and geo-electric exploration on direct and alternating current, which improves the accuracy of control, and let apply contact, contactless and borehole-free methods of measurements.

3. Defined dependences and ranges of the changes of electro-physical parameters of rocks and soils, depending on SER of the pollutant solution allow us to develop methods and techniques to control the process of electrochemical contaminated soils treatment.



- W = 0,1; - W = 0,2; - W = 0,4; - W = 0,6; - W = 0,8

Fig.6:Dependence the of the efficient SER changes $\rho_{Й}$ of Kuzbass soils from moisture saturation coefficient of pores and cracks W, relative content of oil in average weighted $V_м / V_щ$ and salt concentration in electrolyte C, g/l: sand clay – C=0,5 (a), C=50 (b); clay loam - C=0,5 (c), C=50 (d);clay - C=0,5 (e), C=50 (f):

4.References

[1] Prostov S.M. Geo-electrical control of strengthen clay rocks zones / SM Simple, VA Haymaylyainen, MV Gutsal, SP Bakhaeva; RANS. - Tomsk Univ. University Press, 2005. – 127 p.

[2] Stumpf, G.G. Physical and technical properties of rocks and coals of Kuznetsk Basin / G.G. Stumpf, A. Ryzhkov, VA Shalamanov, A.I. Petrov. - Moscow.: Nedra, 1994. - 447 p.
[3] Rzhevskiy V.V. Basic physics of rocks: the textbook for high schools. 4th-ed., Rev. and add. / V.V. Rzhevskiy G.Y. Novik. - Moscow.: Nedra, 1984. - 359 p.
[4] Kobranova V.N. Physical properties of rocks. - Moscow.: Gos. scientific and engineering. ed of oil and mining fuel literature, 1962. – 490p.

Justification Complex Purification Technology Open-pit Mines Wastewater

TYULENEV M.A., LESIN Y.V.

Mining Institute, T.F. Gorbachov Kuzbass State Technical University, 65000 Kemerovo, Russia

In 2012 the total volume of coal mining in the Kuzbass was about 200 million In 2013, it was produced 203 million tons of coal. In addition, there is no reason to believe that in the near future volume of coal will declines. Accordingly, the volume of wastewater discharged by enterprises will increase. So, from 2006 to 2009, there was an increase of polluted water discharge coal mines from 217 to 245 million m^3. Therefore, the problem of water pollution mines governmental waters and career is very important.

Despite its advantages, open coal mining does more than the damage to the tons, including 116 million tons (60.3%) produced on open way, Fig.1.

environment than underground. The most significant impact has opened a way to develop on the hydrosphere and land resources, where the share of the total environmental damage to all elements of the biosphere is 66.4% versus 33.6% for underground mining.

The main contaminants quarry waters Kuzbass mines are suspended solids, oil, iron, etc. For an example, Table. 1 shows the composition of the water discharged from the sectors of the open-pit mine “Chernigovets”.

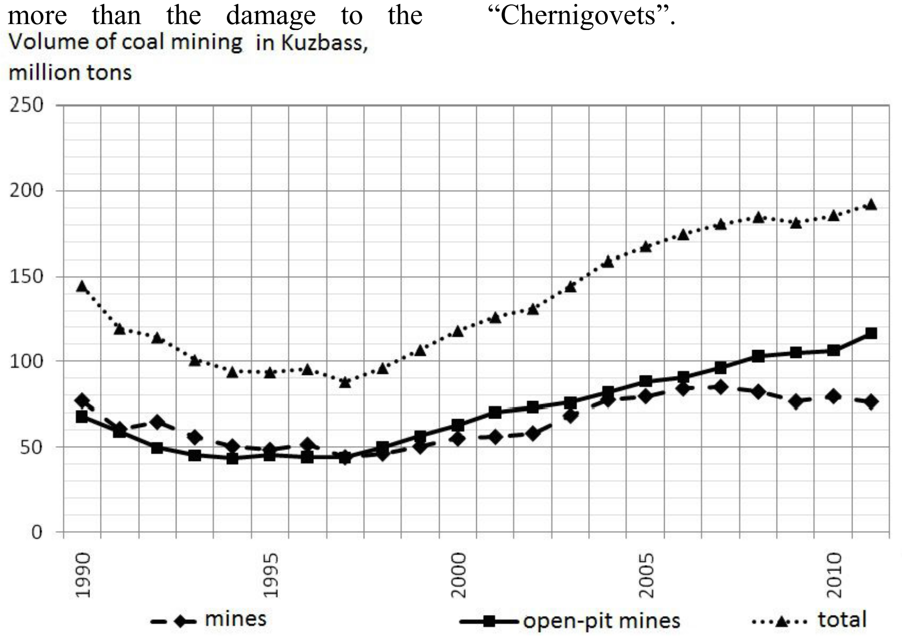


Fig. 1: Dynamics of mining of coal in Kuzbass

Table 1:Consist of water discharged from the sectors of the open-pit mine “Chernigovets”

Indexes	Sectors			
	1	6	7	8
Color	grey	grey	grey	grey
Transparency, cm	2,0	6,5	5,3	4,5
Suspended solids, mg/l	52	200	31	11
Ammonia Nitrogen, mg/l	1,0	1,0	2,0	1,0
Chlorides, mg/l	8,0	14,0	5,0	7,0
Sulfates, mg/l	35,9	40,5	29,1	34,3
Iron, mg/l	0,11	0,88	0,8	0,8
Stiffness, mEq/l	6,5	6,5	5,7	3,3
Calcium, mg/l	2,8	2,8	4,0	3,0
Magnesium, mg/l	3,7	3,7	1,7	0,3
Petroleum products, mg/l	0	0,08	0	0,04
pH	7,0	7,0	7,0	7,0

To date, relatively deeply explored career cleaning wastewater suspended solids, which are the main contaminants. Back in the late 1970s in conjunction with Kuzbass Politechnical Institute workers began the development of production technology open-pit mining wastewater purification by filtration through artificial filter arrays of mining waste – overburden (AFA). This technique [1] in the future is widespread not only in the Kuzbass region, but also in sections of the Far East, Sakhalin, etc. Later this method was improved, in particular, has been proposed and is protected by patents of a Russian Federation design artificial filter array with waterproof jumpers [2], provides increasing degree of purification of water from suspended solids with no additional cost. Also in [3] the mass-transfer of dispersed particles in wastewater filtration described.

Due to the deteriorating environmental situation in industrialized regions, as well as increased penalties for discharge of insufficiently treated effluent very urgent problem of development of technology integrated wastewater purification career at which the cleaning is not only from the main contaminant - suspended solids, but also from other impurities. Brief description of existing technology can be summarized as follows.

Mining waste - overburden - no pre-sorting and preparation of artificial sleeps off filter array with the calculated parameters. In fact, artificial filter array is a bedrock dump, backfilled by peripheral technology with vehicles and a bulldozer. The difference is that being part of AFA path length calculation necessary filtering on the basis of the concentration of suspended matter in the polluted water; tests the ability of the transmission of all incoming water through the array; defined lifetime of the array and other parameters.

Currently, most design institutes and project organizations are calculated[4] AFA parameters according to the "Guidelines on calculation of AFA", approved by Ministry of Coal Industry of the USSR. As an example, on Fig. 2 location of AFA, currently existing on open-pit mine “Prokopievsky”. The main advantages of this method of cleaning quarry waters are low capital and operating costs. Cost of construction of such an array is comparable to the cost of dumping.

In our paper, we propose to use AFA to clean up oil without increasing capital costs for the construction of sewage treatment plants.

The most common methods of purifying water using the effect of the oil adsorption filter, i.e. technology involves the use of various kinds of adsorbents - activated carbon, zeolites, shungites and synthetic filter materials. To the main drawback of this technology, in our view, should include the increase in value of the water purification.

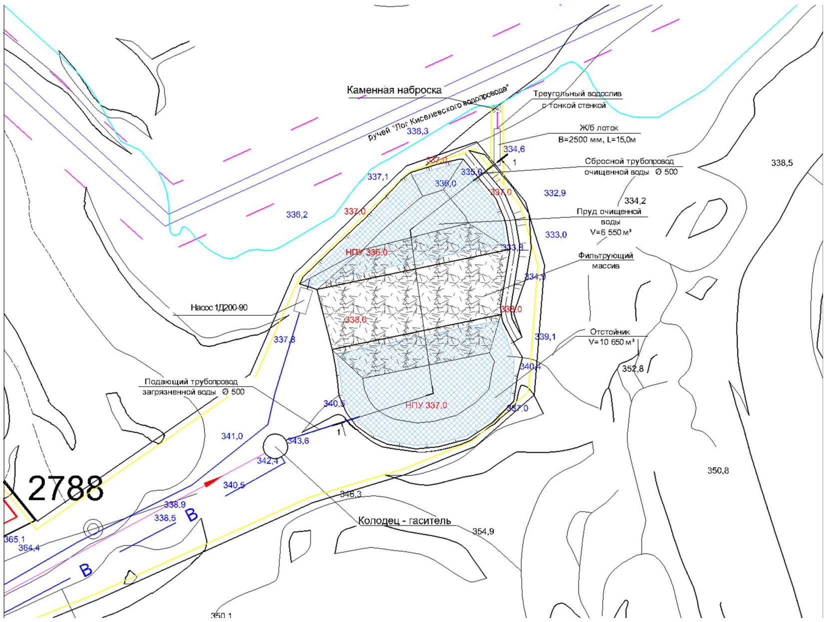


Fig. 2: Location of AFA in the area of “Prokopievsky” open-pit mine

According to the analysis of career wastewater after cleaning through AFA (laboratory "West Siberia Geology", etc.), it was concluded that the content of virtually all contaminants in varying degree-reduced. In other words, we have a qualitative picture of a suitable origin - the effectiveness of AFA is provided not only in the cleaning of suspended solids. Therefore, conducted laboratory studies to-setting nature of the change of oil products.

Found that in the case when the AFA sleeps off entirely from the overburden (sandstone, siltstone, claystone, mudstone) - reduced oil content minimum. If AFA present carbonaceous rocks and coal formed in the conduction of mining operations , the oil content will decrease sharply .

In our opinion, this is due to the fact that coal is a powerful adsorbent. Sorption capacity of the activated carbon can be up to 250 mg/g or more. Sorption capacity of coals up to 10 mg/L [5], and found that the lower the degree of metamorphism of coal, the higher its sorption capacity.

We made calculations cleaning efficiency effluent from oil in artificial filter arrays with different amounts of water discharge, the oil content in the treated water and the percentage of coal in the AFA.

In the conduct of open pit mining loss rate of coal can vary from 5-6% to 15% or more. The loss of coal depends on the room is switched coal seams, their disturbance, structure, and used excavation equipment. For example, when developing thick beds of simple structure with steep bedding, using hydraulic excavators losses amount to 6-

7%, while at working inclined strata complex structure with 1-3 sublayers of overburden inside them, complicated disjunctive violations, the loss rate up to 20%. Accordingly, if the construction of AFA use overburden coming from the mining faces, the share of coal in the AFA will increase significantly, which will provide a more efficient cleanup for petroleum products. Fig. 3 shows examples of the dependences obtained the required volume of the filter array V_{AFA} the percentage of coal in it with different concentrations of oil C_{oil} at constant annual volume of discharge (17.1 million m^3 - the data in the open-pit mine "Kedrovsky").

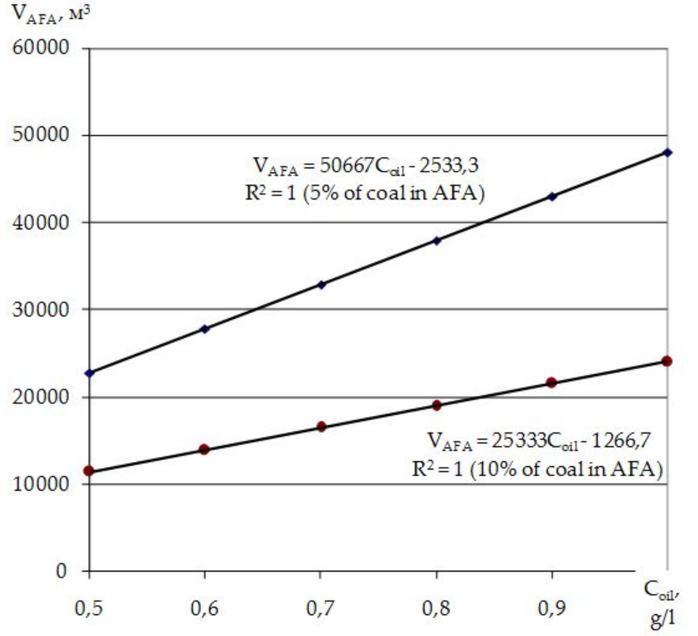


Fig. 3. Dependencies required volume of the filter array V_{AFA} percentage in it coal at different concentrations of oil products C_{oil}.

Thus, we can control the degree of purification of water, changing the composition of the rocks used for the construction of artificial filter array.

References

[1] Certificate 1223958 USSR, MKI B01 D23/10. A method of manufacturing a water filter / Ryzhkov Y.A., Lesin Y.V., Kretov B.K. etc. - Publ. 04/15/86. - Bull. Number 14 / / Opening. Invention. - 1986. - № 14. - S. 24. [in Russian]

[2] Russian Federation Patent number 2225743, MPK7 B01 D24/20. A method of manufacturing a water filter / Yu.V. Lesin, M.A. Tyulenev etc. - Publ. 20.03.2004. - Bull. Number 8. [in Russian]

[3] Lesin Yu.V., Luk'yanova S.Yu., and Tyulenev M.A. Mass transfer of dispersed particles in water filtration in macro-grained media. / Journal of Mining Science. Vol. 46. No. 1, 2010. P. 78-81. [in English]

[4] Tyulenev M.A., Lesin Y.V. Waste water technology on the open-pit mibes of Kuzbass / Mining Information-Analytical-newsletter. Separate issue number 6. Mining engineer 3. Industrial safety and labor protection / Moscow. - 2012. - № OV6. - P. 104-109. [in Russian]

[5] Smirnov A.D. Sorption purification of water. - L., Chemistry. 1982. - P. 92. [in Russian]

Solid Fuel Obtaining by Processing of Coal Enterprises Technogenic Materials

Ushakov Andrey G., Ushakova Elena S., Ushakov Gennady V.

Chemical Technology of Solid Fuel of Oil and Gas Technologies Institute, T.F. Gorbachev Kuzbass State Technical University, 650000 Kemerovo, Russia

Abstract: The work is devoted to the problem of wastes processing and utilization of coal-mining and coal processing enterprises. It is proposed to use coal-waste in solid composite fuel technologies with the use of innovative binder based on the activated sludge biological treatment facilities. Technological scheme of developed technology is presented.

Keywords: coal-mining and coal processing wastes, solid composite fuel, binder.

1.Introduction

It is known that the enterprises of the fuel and energy sector, as extractive resources and the receiving of them energy, are the main sources of anthropogenic impact on ecosystems. Intensive development of coal mining and coal processing enterprises have an impact on the lithosphere, causing the increase of volumes of solid carbon-containing wastes with a high percentage of coal sludge materials, screenings and dust. For example, in the mining industry of Russia the total mass of all unprocessed waste reaches 45 billion tons, and the total area occupied for its storage, more than 250 thousand hectares of land [1]. It is estimated that the extent of the formation of solid combustible waste in various industries can be from 30 up to 70 % from the basic volume of production.

2.Characteristic of the work

Considering the enterprises of a coal mining is possible to allocate the following kinds of waste coal [2,3]:

– Coal dust, formed at the enterprises of the coal industry;
– Coal screenings, produced at the enterprises of the fuel and energy sector in the classification of coals and the allocation of factions, suitable for burning in boilers;
– Coal sludge – high-ash and micro dispersed particles, which is a waste of technological processes of production of coal.

Coal technological wastes are formed in the activities of the coal-mining enterprises – mines, cuts, and also concentrating factories. Sometimes, increasing gross coal production leads to increases loss is more than 50 %. The technical condition of many coal preparation plants and their technology are such that the waste coal content of coal reaches 25-26 %. One of the negative impacts of coal cuts is air pollution by industrial emissions (from explosions, internal combustion engines and other) and dust particles from the surface of the boards of mines and waste dumps [4, 5].

Such amount of waste is an important energy resource that can be the foundation of organization of new kinds of molded fuel production.

But for obtaining high-quality fuel granules with high consumer properties that meet the requirements of durability, abrasion, size, and so on, it is needed for binding substance, which largely depend on the final properties of the product. The choice binder is an important step in determining many of the properties of the received granules. The parameters that define the properties of the binder are the chemical nature, composition, and their physical properties.

Varieties used binder is quite wide. They can be divided into two broad classes [6, 7]:
– Organic – concentrates of sulfitno-spirit bards, oil bitumen, pitches and resin oil and coal origin, and so on;
– Inorganic – liquid glass, cement, clay, gypsum binder, bentonite, etc.
Binder requirements to ensure the quality of molding process [8]:
1. High output of fuel (95-98 %) necessary strength to the required standards.
2. Environmental security: the absence of harmful substances in the composition of the binder or the absence of their emission during the subsequent operation of the obtained product.
3. Reliable and stable operation of main and auxiliary equipment for transportation by pipeline raw materials and products, mixing, forming processes.
4. Getting formed fuel that complies with the requirements of the energy companies.
The analysis of binder properties shows that they do not meet all the above requirements.
Thus, there is the problem of search of the optimal binder, which is also easily accessible to the implementation of the molding process and most importantly inexpensive as the economic component in any technology in many respects is crucial.
Products of processing excessive active silt inevitably formed on the stations of biological treatment of industrial and domestic wastewater can use as such substances.
In T.F. Gorbachev Kuzbass State Technical University studies for obtaining solid composite fuel based on waste of the coal enterprises (table 1) and excessive active silt, held microbiological processing (table 2).
Two types of mixtures for the production of fuel granules are reviewed:
1. Coal waste/binder.
2. Coal waste/binder with modifying additives.
To study the influence of the modifying additives on the properties of granules and pelletization progress the mixture was introduced shredded paper weight (table 3).
The basic properties of the received granules are given in table 4.
The results of laboratory studies are the technological processing scheme of fuel pellets producing (figure).

Table 1. Properties of coal waste

Parameter	Coal slurry	Coal screenings
Moisture content (W^a), %	1.6	5.3
Ash value (A^d), %	37.7	15.9
Fractional composition, %:		
+1 mm	11.9	73.4
1-0,7 mm	5.8	14.4
0,7-0,5 mm	6.6	4.3
– 0,5 mm	75.7	7.9
The calorific value ($Q_в^d$), MJ/kg	22.5	24.0

Table 2. Characteristics of activated sludge

Moisture content (W^a), %	Ash value (A^d), %	Density, кг/м^3	S content, %
80-90	25-35	1025-1070	0.02-0.05

Table 3. Formulation of fuel pellets with modifying additives

The components, % wt.	Mixture	
	1	2
Coal screenings	17	16
Coal slurry	44	44
Fermented active sludge	39	38
Shredded paper	–	2

Table 4. Characteristics of fuel granules

Parameter	Mixture	
	1	2
Ash value (A^d), %	21	26
Resistance to abrasion, %	46.3	72.2
The calorific value (Q_s^d), MJ/kg	21.9	22.0

According to the scheme: active sludge treatment plants loaded into the hopper 5, where gyratory pump pumped into the digester 1, which is subjected to anaerobic digestion with production of biogas. The scheme provides 3 digester, running in parallel. The total period of fermentation is 16 days.

For optimal humidity of the mixture into the digester add water, dosing is carried out automatically (weight batchers). The digestion process is carried out at periodic stirring. The effectiveness of anaerobic digestion is determined by the temperature of fermentation mixture. Optimum temperature of the mixture in the device is 37 ℃.

The biogas generated in the process of fermentation, enters the tank 6, where it is collected and then used for technological needs.

Biogas should be cleaned from acid gases before using. Designed site cleanup (not shown) using ammonia water, in which the acid gases (carbon dioxide, hydrogen sulfide) contact with ammonia – formed ammonium salts, used in various industries. After cleaning, biogas, containing mainly methane (up to 98-99 %), it is proposed to use for space heating and so on, in the home. Consumers of biogas are also being boiler plants, supplying the population with hot water, diesel electrical.

The remaining in the digester at the end of the processing period fermented mass by pump 2 is pumped into the capacity for the preparation of molding mixture, which is served in the granulator 7.

Received pellets come in a tumble dryer, dried granules sent for packaging and next to the consumer.

3.Conclusion

Thus, getting molded fuel based on waste of the coal enterprises using organic binder will solve the problem of waste, and is accompanied by positive economic effect. So for heating the heat carrier up to the same temperature (60^{o}C) , the combustion of various raw materials are spent 2 kg of firewood, 1.3 kg of coal and 1.4 kg developed granules. Designed fuel can be used for heating of private houses and cottages, small and medium-sized boiler-houses.

It is established that the cost of pilot production of 1 ton of fuel pellets on the experimental industrial plant with a capacity of 2 500 tons/year of pellets will be 2 380 rubles. If scaling up power and industrial plants are conducted, production costs will be reduced by 75 %.

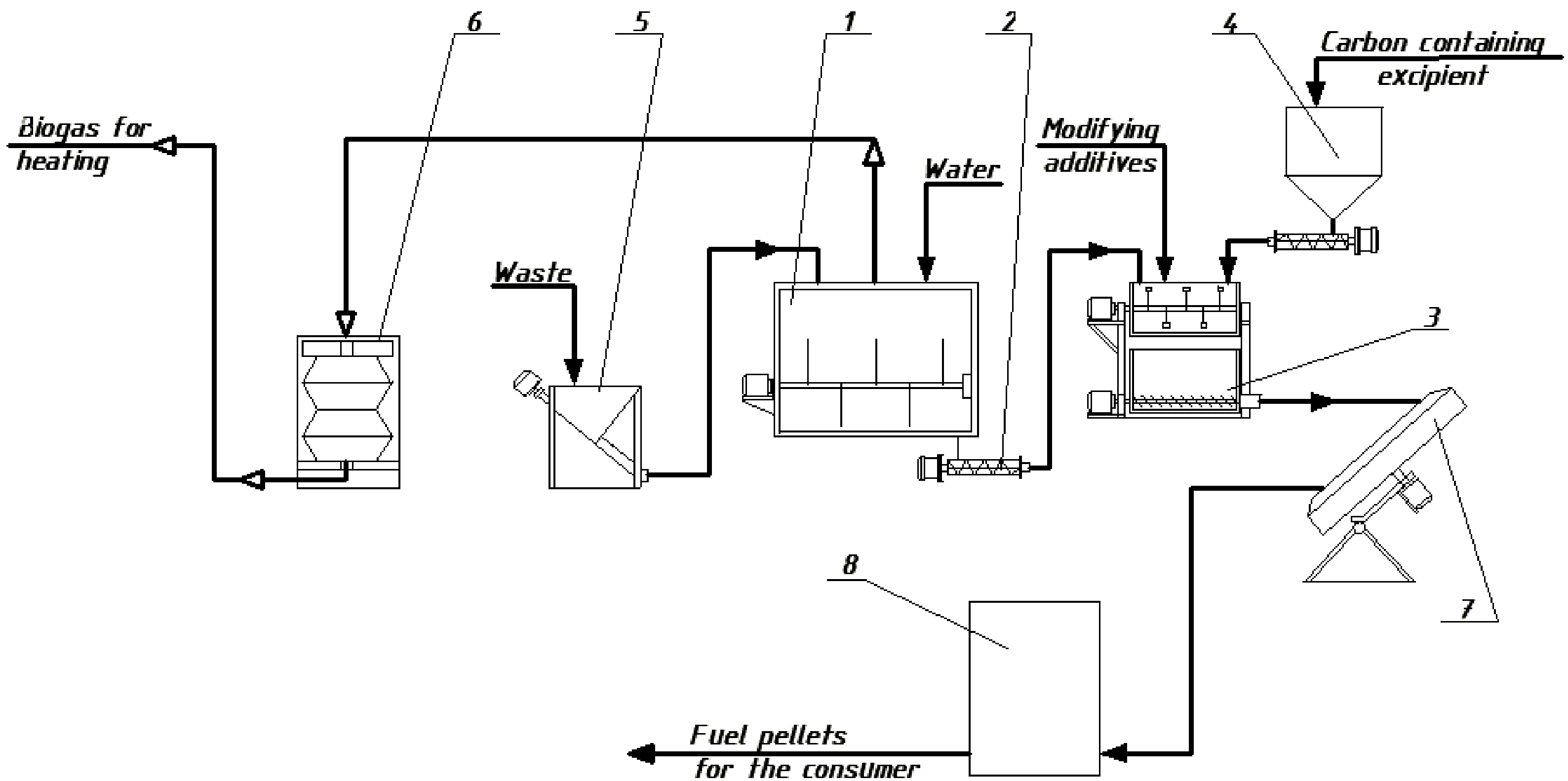


Fig. Technological scheme of technogenic coal formations processing with fuel pellets obtaining: 1– digester; 2 - screw (gyratory) mortar pump; 3 – mixer; 4 – bin coal slurry; 5 – screw (gyratory) mortar pump with a tank; 6 – gasholder; 7 – granulator; 8 – industrial tumble dryer

4.References

[1] Klimov S.A.,Fraiman G.B., Gruzinov G.P. Complex oil shale using. – Lipeck, 2000. – 179 p.

[2] Shapchenova O.A. The influence of anthropogenic emissions Berezovskaya GRES-1 on biological activity of soils // Environmental Risk: Materials of the 2nd all-Russian conference. – Irkutsk, 2001. – p. 182-185.

[3] Volkova A.V. The influence of heat-power engineering on the environment // Modern problems of technical, natural Sciences and Humanities: Materials of the all-Russian conference. P. 1. – Gybkin, 2007. – p. 88-91.

[4] Glazkova A.V., Stroinova V.N. Air pollution from thermal power plants // Problems of geology and exploration of mineral resources: Proceedings of the 3rd academician M.A. Usova International scientific symposium of students, post-graduates and young scientists in the framework of the Russian scientific and social program for youth and schoolchildren Step into the Future – Tomsk, 1999. – p. 354-355.

[5] Klika Z., Bartonova L. The effect of different modes of Czech Republic thermal power plants on the behavior of sulfur and minerals coal combustion // Development of Coal Chemistry and Chemistry of Carbon Materials in the XXI Century: Theses of reports of Scientific Council Enlarged sessions, 2003. – M., 2003. – p. 41.

[6] Elishevich A.T. Briquetting of coal with a binder. – M., 1972. – 216 p.

[7] Krohin V.N. Briquetting of coal. – M.: 1984. – 224 p.

[8] Lobuch A.M. Briquetting coke breeze with a binder and coking partially briquetted charge in the manufacture of metallurgical coke: The dissertation for PhD. – Ufa, 2000. – 180 p.

Experience for Coal Mine Methane Utilization to Generate Thermal and Electric Power

TAILAKOV Oleg V., ZASTRELOV Denis. N., UTKAEV Evgeniy A., SMYSLOV Alexey I., KORMIN Alexey N.

Institute of Coal SB RAS 650000 Kemerovo, Russia

Abstract: Here an experience on utilization of coal mine methane (CMM) to generate thermal and electric power at Kuzbass coal mines is given. A process model of CMM utilization is presented in the form of a Petri net.

Keywords: coal mine methane, thermal power, electric power, power generating plant.

1.Introduction

Nowadays, the majority coal mines of Russian mainly release methane into the atmosphere and almost never utilize it. Whereas, the extracted coal mine methane (CMM) can be processed for generation of thermal and electric power, which can be used by coal companies for own needs and/or delivered to an outside customers [1].

2.Work description

Nevertheless, several projects on CMM utilization were fulfilled in Kuzbass. Mine 'Krasnogorskaya' in Prokopyevsk introduced modular boiler of 0.7 MW capacity for thermal power generation (Fig. 1). The equipment allows using air-methane mixture with a methane concentration not lower 25%.

Fig. 1: Modular Boiler at 'Krasnogorskaya' mine

At the mine gas generating plant of 0.9 MW capacity for electric power generation was put into operation. For sufficient work of the generator the concentration of methane in air methane should be not lower 35%. This plant has been operating at the mine since 2009 (Fig. 2).

Fig. 2: Gas Generating Plant at ‘S.M. Kirov’ mine

In 2012 ‘Komsomolets’ mine implemented a project for methane utilization by generation unit with the set electrical capacity of 0.4 MW (Fig. 3). The technology of simultaneously use of two sources of air-methane: low (less than 3.5%) and high (over 25%) concentration of methane was successfully tested.

Fig. 3: Generating station at ‘Komsomolets’ mine

Enhancement of degassing systems efficiency, introduction of modern methods of methane extraction [2] would improve the volume of the extracted air methane. One of the possible intensification methods for methane production is pumping of carbon dioxide into coal seams to release methane [3].

Due to gradual development of CMM utilization projects at the coal mines, the issue of assessment of the efficiency of power plants and reducing possible downtime is very urgent. To evaluate the performance of CMM utilization projects it is possible to use directed graphs, which will display the structure of the investigated systems, technological process of CMM utilization, and economic models to describe their main economic data for CMM utilization projects.

The process model of CMM utilization is presented in the form of a Petri net $N = \{P, T, I, O, M_0\}$, which consists of a finite set of positions $P = \{p_1, p_2, ..., p_m\}$, corresponding to the main technological units, final set of transitions $T = \{t_1, t_2, ..., t_n\}$, characterizing the process of the thermal power generation, connected by arcs: I - input function, O - output function, which reflects the equipment work, and also has primary marking M_0, which corresponds ventilation air methane and thermal power at the initial stage of work of the modular boiler. Operation of the network N is carried out by means of switching transitions. Through the use of mathematical Petri net, a directed graph N_1 (Fig. 4) was built.

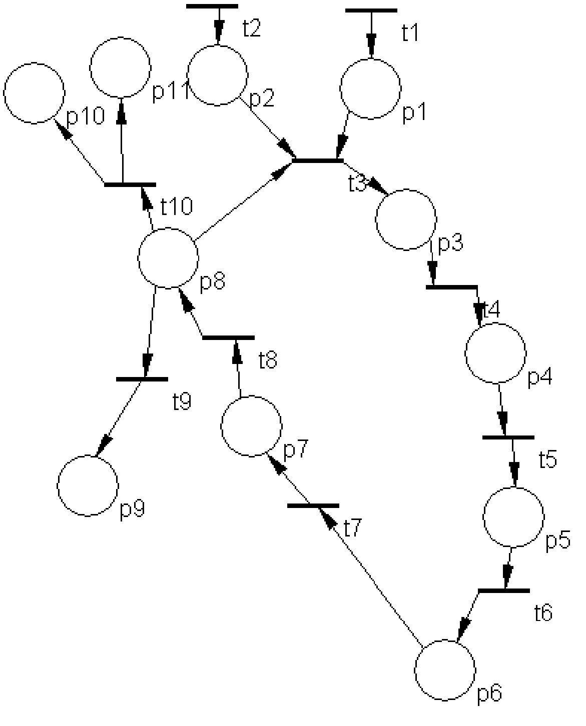


Fig. 4: Network N_1, reflecting the utilization process of CMM in the modular boiler

The methane utilization process is characterized as follows: Air methane is extracted by vacuum pumping unit p_3, then it is fed to the condensate collector number 1 p_4 for cleaning from dust and moisture, then to the condensate collector number 2 p_5 for further purification and then to the gas pressure controller p_6, which smooth out pressure kick in a pipeline. Free of dust and moisture air methane is fed to a gas burner p_7, where methane is mixed with air to achieve the required quality. On the next stage the gas mixture is fed into the furnace p_8, where methane is combusted generating thermal power. Part of the thermal energy is used for own needs of the boiler, the remaining energy is fed into the shower facilities of the mine p_{10}. (Table 1)

Table 1: Interpretation of items ***P*** and transitions ***T*** net N_1

Позиции ***P***	Переходы ***T***
p_1 – gas pipeline; p_2 – switchboard; p_3 – vacuum pump unit; p_4 – condensate collector №1; p_5 – condensate collector №2; p_6 – gas pressure control; p_7 – burner; p_8 – furnace; p_9 – chimney; p_{10} – system of heat consumption; p_{11} – meter.	t_1 – methane production; t_2 – electricity to a switchboard; t_3 – methane to vacuum-pumping station; t_4 – methane feeding; t_5 – methane cleaning; t_6 – further purification of methane; t_7 – smoothing out pressure kick in pipeline; t_8 – mixing methane and air; t_9 – feeding of exhausted air to chimney; t_{10} – thermal power to thermal consumer grid.

3.Conclusions

The designed directed graph of CMM utilization process in modular boiler for generation of thermal power conducts numerical experiments and performs assessment of the properties of the network model. The simulation results can be used to adjust the technological modes of modular boiler to improve the efficiency and sustainability of the equipment.

Introduction of the energy efficient technologies based on CMM utilization allows efficient use of valuable energy resources to generate, for example, thermal and electric power. Successful examples of such projects in Kuzbass allow further development utilization of coal mine methane.

4.References

[1] Backhaus C., Bezpflyug V.A., Mazanik EV, Hoppe C. Experience of implementing mobile Thermal Power Plants on CMM // Coal. - 2009. - № 11 - 50-53p.

[2] Polevshikov G.Y., Kozyreva E.N., Shankevich M.V. Enhancement of efficiency of the integrated degassing management at coal face operations // Bulletin of the science center on safety in coal industry. Scientific and Technical Journal, Kemerovo, 2012. - № 2. - 20-27p.

[3] Tailakov O.V., Zastrelov D.N., Tailakov V.O., Kormin A.N. Capture and storage of carbon dioxide at Kuzbass coal seams // Gas Industry № 12/699/2013, Moscow: Publishing House ‘Gasoil press’ 2013. - 86 – 87p.