

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 10/70A)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 of excavators (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 $^{\circ}\text{C}$ 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 in base 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. – publisherIntrosopy 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.

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

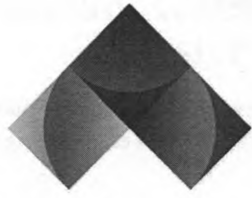
MINING 2014



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



泰山学术论坛
Taishan Academic Forum

MINING
2 0 1 4

**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

© ATLANTIS PRESS, 2014

www.atlantis-press.com

ISBN: 978-94-62520-28-8

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

All rights reserved. No part of this book may be reproduced, translated, stored or transmitted in any form or by any means, including electronic, mechanical, photocopying, recording or otherwise, without prior permission from the publisher.

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

1. Selection of a rational form for the steel winding tower as a preventive measure to increase its industrial safety
Elena G. Kassikhina., Vladimir V. Pershin, Nikita O. Butrim, Weiguo Qiao 1
2. Engineering and process design solutions for the vertical shaft completion
Weiguo Qiao, V.V. Pershin, E.G. Kassikhina, N.O. Butrim 5
3. Study on construction of embedded bolt sleeve's precision in massive concrete
Chongge Wang, Jiachuan Liu 11
4. Economic and technological criteria of choosing the support for construction of mine workings
Song Weijie, V.V. Pershin, Yu. A. Masaev, V. Yu. Masaev, Weiguo Qiao 15
5. Constructions parameters updating of protecting apron under deepening of vertical shafts
Vladimir V. Pershin, Aleksandr I. Kopyitov, Mikhail D. Voitov, Akhmed A. Wetti, Ivan V. Zhuk 21

Part II. Mining theory, method and technology

6. Highwall mining stability
Baotang Shen 25
7. Study on the movement law of overburden strata during mining strip pillar with paste
Guo Weijia , Li Yangyang, Zhang Baoliang, Wang hailong, Sun xizhen 38
8. Numerical simulation study on influencing factors to part-filling pillars' stability
Wanpeng Huang, Yanghui Ren, Lin Gao 44
9. Research on strip filling surface subsidence rule
Shi Yongkui, Qi Minhua, Zhang Jingyu, Hao Jian 52
10. Characteristic analysis of surface subsidence in deep mining
Chang Xikun, Wang Rongfa , Zang Jincheng 62
11. Mechanical models and support technologies for retaining gob-side entry
Yunliang Tan, Yanchun Yin, Jianguo Ning, Tongbin Zhao 67

12. Influence of mining and retaining parameters on evolution of hazard rockburst in strip-pillar mining <i>Wang Chunqiu, Li Wenshuai, Gu Shitan, Ma Chuanle, Xiao Zhimin</i>	73
13. The application of fuzzy analytic hierarchy process for thick coal seam mining methods in China <i>Wang Lei, Yang Yang, Cheng Huimin</i>	84
14. Simulation study of dynamic response of bolt support in impact roadway <i>Liu Fan, Liu Wenjie, Wang Tongxu</i>	93
15. Rapid heading technology of coal seam contained iron sulfide nodules <i>Xinglin Wen, Mengmeng Dong, Ran Fan, Kai Sun, Zhongjian Zhang</i>	99
16. Simulation and analysis on characteristics of lower-group roadway surrounding rock under deep near interval coal seam <i>Zhang Peisen, Wang Hao, Lin Dongcai, Kan Zhongui</i>	107
17. Study on grouting anchor cable supporting technology of roadway through extra large fault fracture zone <i>Liu Jin-xiao, Jing Ji-dong, Feng Yi-yu, Wu Lei, Zhang Pei-sen</i>	114
18. Study on optimal design of concrete-filled steel tube support in coal mine <i>Liu Limin, Zhao Shijun, Cao Junzhi, Qin Zhongcheng</i>	119
19. Measurement and analysis on failure height of overburden strata of mechanized sublevel caving in shallow region of Baodian coal mine <i>Li Fuchen, Zhang Wenquan, Guo Wei, Wang Zongsheng, Li Yunjiang, Liu Yanxin</i>	126
20. Study on the rapid excavation technology of deep large cross-section rock tunnel <i>Liu Xinjie, Kong Dezhong, Song Gaofeng</i>	133
21. Large deformation control principle and reinforcement technique for solid coal rib of large-section gob-side tailentry in thick coal seam buried deeply <i>Zang Chuanwei, Chen Miao, Tan Yunliang, Ma Chuanle, Meng Xiangjun</i>	138
22. Durability test of gangue paste filling material <i>Liu Yin, Wang Qifeng, Zhang Haoqiang</i>	144
23. Coal deposits' mining with high content of natural radionuclide <i>Pavel B. Avdeev, Galina P. Sidorova</i>	150
24. Advanced technology based on new technological and organizational principles of spatial development of front of mining operations at open pits <i>Alexei V. Selukov</i>	156

25. Fractal characteristics of mudstone microscopic morphology in MATLAB environment <i>Huang Dongmei, Zhang Zhenquan, Lin Xiaofei, Li Huaxue,</i>	161
Part III. Mining equipment and machinery	
26. Modeling of hydraulic power cylinder seal assembly operation <i>Gennady D. Buyalich, Konstantin G. Buyalich</i>	167
27. Formation Auger equipment reliability <i>Yuri V. Drozdenko</i>	171
28. Stress-deformed state knots fastening of a disk tool on the crowns of roadheaders <i>Aleksey Khoreshok, Leonid Mametyev, Andrey Borisov, Aleksey Vorobiev</i>	177
29. Preventive maintenance of mining equipment based on identification of its actual technical state <i>Vladimir Kovalev, Boris Gerike, Aleksey Khoreshok, Pavel Gerike</i>	184
30. Evaluation of explosion protection means of mine electrical equipment for operation in excavations of coal mines <i>Vladimir Efremenko, Roman Belyaevsky</i>	190
Part IV. Construction safety in mines and underground engineering	
31. Study of asymmetric failure law and support for large embedded depth roadway driving along the roof in inclined coal seam <i>Cheng Guoqiang, Yan Mingju, Zhu Hongli, Yu Haifeng</i>	195
32. Analysis on human safety behavior mode during the production process <i>Zhou Gang, Xue Jiao, Wang Hao, Zhang Qi</i>	203
33. Control design of roof rock for advance blasting in roof on gob-side entry without roadside support <i>Zhang Kai-zhi, Liu Bao-cheng</i>	211
34. Drilling strata movement detection experiment on failure law of overlying strata movement <i>Shijian Yu, Zhaobin Liu</i>	218
35. Research of mining depth influence on floor coupled stree-seepage characteristics <i>Yin Liming, Shi Nan, Chen Juntao</i>	224
36. Rock burst danger warning and large diameter drilling pressure-relief technology in fully mechanized caving island coal face <i>Gu Shitan, Huang Ruifeng, Tan Yunliang, Jiang Bangyou, Li Wenshuai</i>	231

37. Numerical simulation of stress relieving and analysis of influencing factors on geostress measurement <i>Zhao Tongbin, Zhang Minglu, Li Zhanhai, Zhang Ze</i>	241
38. Numerical simulation of roadway gas migration based on the lattice Boltzmann method <i>Zhao Zhi-gang, Zhang Yong-bo, Tan Yun-liang</i>	248
39. Research status of wet duster in fully mechanized workface <i>Zhong Yang, Wu Meng-meng, Yang Xin-xiang, Xiao Wei</i>	258
40. Development and application of integrative jumbo for deep hole sampling <i>Wang Gang, Yang Xin-xiang, XiaoWei, Wu Meng-meng</i>	273
41. Analysis on the old gob water inrush accident of Kunlun mine in Zibo <i>Jiang Hua, Gai Wenren, Zhao Fu, Zhang Xin, Liu Hailin</i>	282
42. Risk assessment of floor water inrush in deep mine based on grey system theory <i>Liu Weitao, Pan Xiaofeng, Liu Huan, Shen jianjun</i>	288
43. The water-disaster characteristic of coal mine in Shandong province and the research on prevention and control countermeasures <i>Zhang Wenquan, Ren Zhongping, Jiang Hua, Sun Gaoliang, Hang Qianqian, Dong Yi</i>	294
44. Determination of rational coal and rock pillars height of coal mining under the loose aquifer <i>Wang Jianhu, Shao Mingxi, Shang Yanfeng, Cao Siwen, Zhang Xin, Hu Chuanmeng</i>	306
45. Research on water resistance of the hanging wall of the fault tilting water-resisting key strata model <i>WangYuhe, Zhang xinglei, Wang Houchen, Cheng Jiulong, Guo Wei</i>	312
46. Study on test method of rock acoustic emission and damage evolution characteristics under triaxial compression <i>YangYongjie, Ma Depeng, He Yanxin, Xing Luyi</i>	321
47. Research advances of heterogeneity representation methods for rocks <i>Yanchun Yin, Yunliang Tan, Weiyao Guo, Minglu Zhang</i>	327
48. The numerical simulation of the influence from fault dip angle on coalface pressure <i>Zhang Li, Xia Junfeng, Zang Chuanwei</i>	333
49. The research and application of the hard roofs forced caving technology in short wall stopes <i>Gao Min, Wei Jiuchuan, Ma Xiaoqi</i>	339

50. To the question of the destructed rock mass movements regime assessment <i>Victor S. Kharkovskyi, Valery M. Plotnikov, Eugenia V. Komleva, Olessya A. Kogay, Anna S. Korobkina, Anne V. Harlamova, Yuri N. Goncharov, BekturKh. Balikbayev</i>	345
51. Simulation of stress-strain state of the reinforced soil foundation for structures <i>Sergei M. Prostov, Mikhail V. Sokolov</i>	350
52. Inert compositions for underground fire fighting in mines <i>Vyacheslav Portola, Nima Galsanov</i>	356
53. Modeling peculiarities of reinforced crack of hydraulic fracture of coal seams for estimation of their permeability <i>Mihail Alekseevich Baev</i>	361
Part V. Mines, underground engineering operation and management	
54. Application of safety check list on confidential inspection <i>Chen Hai-yan, Gao Jian-guang, Xu Yun-fei</i>	367
55. Coal mine safety influence factors causality analysis and function relationship construction based on system dynamics <i>Chen Jing, Yang Yongjie, Cao Qinggui</i>	375
56. Research and application of heat exchange system in Sun village coal mine <i>Li Xinghua, Xiao Bin, Zhang Limei</i>	381
57. Research of safety pre-control management system of power plants <i>Li Xinghua, Wang Suli</i>	387
58. Study on early warning method of coal mine accident about ventilation, gas, dust and fire <i>Lin Xiaofei, Song Shouxin, Huang dongmei</i>	392
59. The influence of coal mining on groundwater resources and the analysis of water resources protection countermeasure <i>Zhang Hongri, Sheng Yuanyuan, Zhang Guibin, Dong Shizhuo, Liu Yu</i>	398
60. The transport systems of simulation and optimization of Dingfeng's slime and gangue power plant <i>Li Xinghua, Wang Danying</i>	406
61. Rare earth elements in Kuznetsk coals: ability to excavate and new functional materials <i>Tatyana G. Cherkasova, Elizaveta V. Cherkasova, Elza S. Tatarinova, Alena A. Bobrovnikova, Irina P. Goryunova, Yuliya A. Mihaylenko, Anastasia V. Tihomirova, Irina V. Isakova</i>	418

62. The main characteristics of freight on hot streams <i>Natalya V. Erofeeva, Irina N. Chebotova</i>	421
63. Study of the process of the polymer flocculants degradation used for coal processing <i>Sergey D. Evmenov, Galina L. Evmenova</i>	424
64. Safety of mining engineering buildings and facilities under Fem analysis and catastrophe theory <i>Vladimir Viktorovich Pershin, Dmitriy Ivanovich Nazarov</i>	428
65. Physical basis of the controlled electrochemical treatment of soils from oil products <i>Sergey M. Prostov, Maxim B. Gucal, Evgeniy F. Shabanov</i>	433
66. Justification complex purification technology open-pit mines wastewater <i>M.A. Tyulenev, Y.V. Lesin</i>	441
67. Solid fuel obtaining by processing of coal enterprises technogenic materials <i>Andrey G. Ushakov, Elena S. Ushakova, Gennady V. Ushakov</i>	445
68. Experience for coal mine methane utilization to generate thermal and electric power <i>Oleg V. Tailakov, Denis. N. Zastrelov, Evgeniy A. Utkaev, Alexey I. Smyslov, Alexey N. Kormin</i>	450
69. Study on the dissipation mechanism of shock and vibration energy in a stress release area of deep roadway <i>Jianguo Ning, Jun Wang, Xuesheng Liu, Yunliang Tan</i>	454