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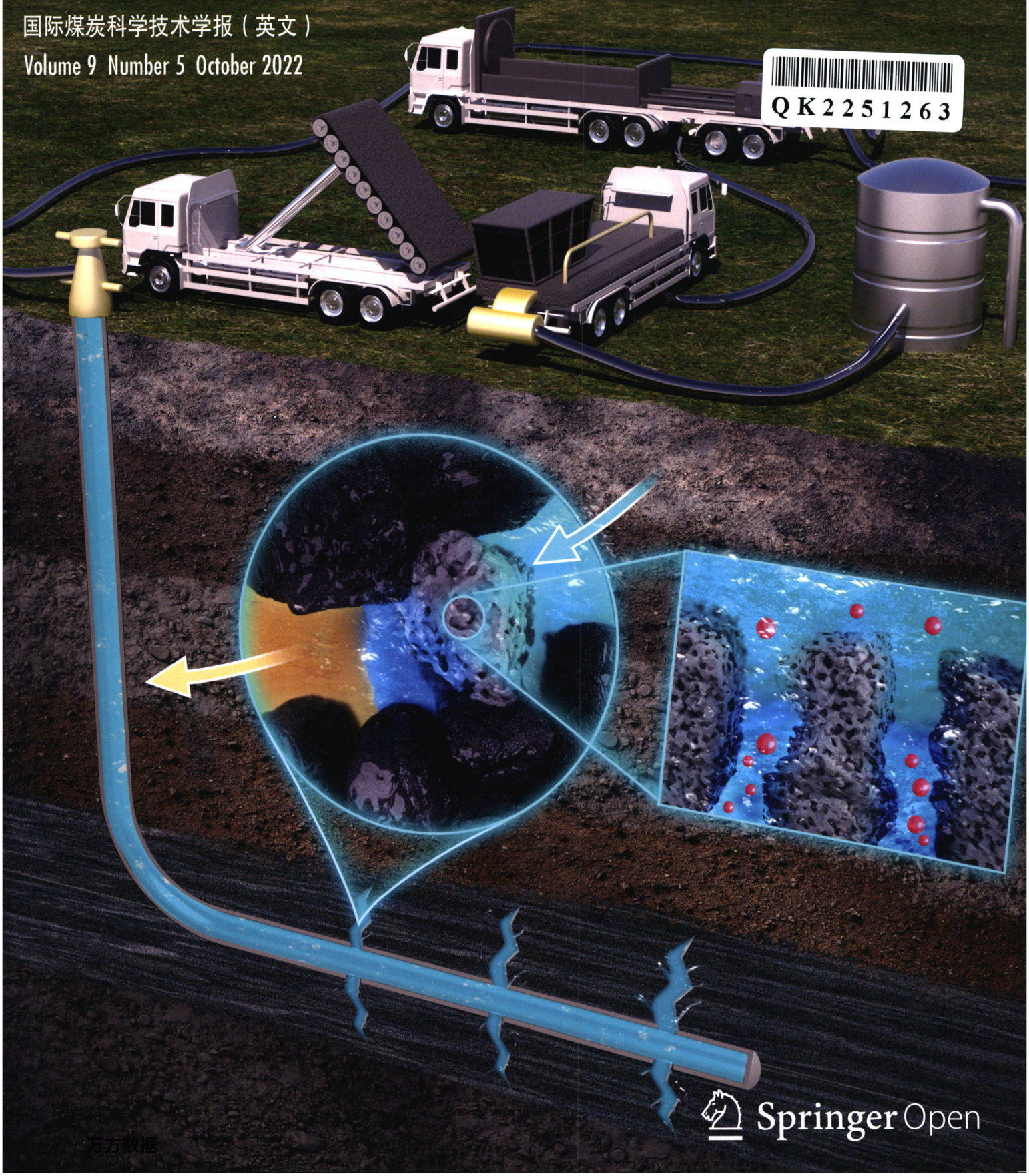

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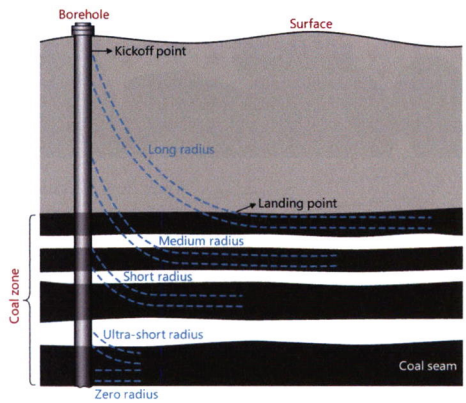
INTERNATIONAL JOURNAL OF COAL SCIENCE & TECHNOLOGY

Review

DOI: https://doi.org/10.1007/s40789-022-00540-x

Drilling and completion technologies of coalbed methane exploitation: an overview

Tianshou Ma, Jinhua Liu, Jianhong Fu & Bisheng Wu

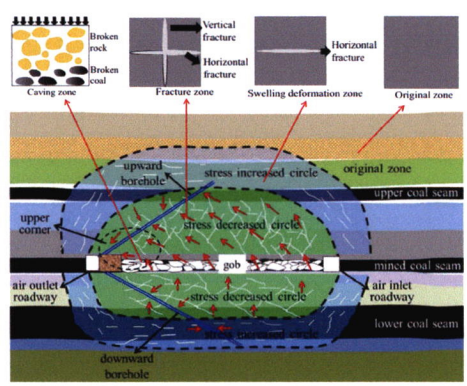


Abstract: Coalbed methane (CBM) drilling and completion technologies (DCTs) are significant basis for achieving efficient CBM exploration and exploitation. Characteristics of CBM reservoirs vary in different regions around the world, thereby, it is crucial to develop, select and apply the optimum DCTs for each different CBM reservoir. This paper firstly reviews the development history of CBM DCTs throughout worldwide and clarifies its overall development tendency. Secondly, different well types and its characteristics of CBM exploitation are summarized, and main application scopes of these well types are also discussed. Then, the key technologies of CBM drilling (directional drilling tools, measurement while drilling, geo-steering drilling, magnetic guidance drilling, underbalanced drilling and drilling fluids), and the key technologies of CBM completion (open-hole, cavity and under-ream completion, cased-hole completion, screen pipe completion and horizontal well completion) are summarized and analyzed, it is found that safe, economic and efficient development of CBM is inseparable from the support of advanced technologies. Finally, based on the current status of CBM development, the achievements, existing challenges and future prospects are summarized and discussed from the perspective of CBM DCTs.

DOI: https://doi.org/10.1007/s40789-022-00533-w

Experimental study of coal flow characteristics under mining disturbance in China

Lei Zhang, Zihao Kan, Cun Zhang & Jun Tang



Abstract: With annually increased coal mining depth, gas extraction becomes more and more problematic. The gas extraction effect depends on coal seam permeability, which, in turn, is affected by many factors, including loading and unloading stresses and strains in the coal seam. Stresses induce internal cracks, resulting in cleats and gas emission channels, the coal seam permeability permanently changes accordingly. To clarify the stress-induced effects on coal seam permeability, this survey summarized the available approaches used to link the stress path and seepage law in the coal body seepage law, which can be classified into two design methods: single load variation and combined field mining method. The characterization methods used to observe the surface of coal samples and three-dimensional reconstruction include electron microscopy, CT scanning, and Nuclear Magnetic Resonance (NMR). According to the stress paths designed by the above two approaches, the seepage laws and similarities of three kinds of coal samples with the fractured structure were summarized in this paper. The following directions are recommended to study the seepage law of coal bodies with three kinds of fractured structures under stress. Firstly, the stress path of the experimental coal body should be designed by the combined field mining method. The stressed environment of a deep coal seam is complicated, and the axial and confining pressures change simultaneously. Therefore, one cannot fully reflect the real situation on-site by studying permeability evolution alone. Secondly, during the coal seam mining, the stressed state changes from time to time, and the development of coal seam fractures is affected by mining. When studying the stress effect on seepage of coal samples, the fractured structure of coal samples should be considered. Finally, the available structural characterization methods of coal samples can be combined with the 3D printing technology, which would produce artificial samples with the fractured structure characteristics of natural coal.

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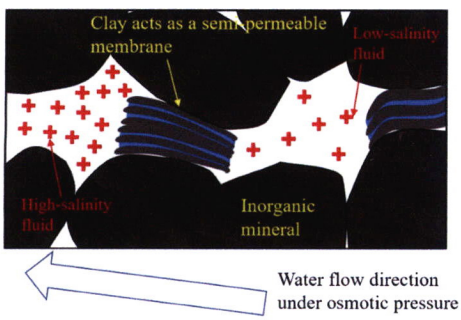
Research Articles

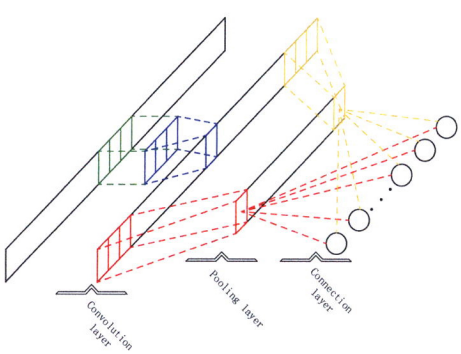


DOI: https://doi.org/10.1007/s40789-022-00546-5

Spontaneous imbibition characteristics of shale oil reservoir under the influence of osmosis

Yuliang Su, Qinghao Sun, Wendong Wang, Xincheng Guo, Jilong Xu, Guanqun Li, Xiugang Pu, Wenzhong Han & Zhannan Shi

Abstract: The spontaneous imbibition (SI) process in shale oil reservoirs is not only influenced by capillary force, but also by the osmotic pressure between the fracturing fluid and formation water in the nanopores media. In this study, experimental methods are used to investigate the mechanisms of osmosis in the SI, taking into account the presence of initial formation water in shale oil reservoirs. To investigate the effect of osmosis, SI experiments were performed on the fine-grained felsic shale of the Qikou sag of Dagang oilfield. Low-field NMR testers and high-precision electronic balances are utilized for the measuring of oil–water migration. The results show that, when $S_w \neq 0$, high-salinity fluid SI can be divided into four stages: initial imbibition stage, drainage stage, secondary imbibition stage and stationary stage; when $S_w = 0$, there is no drainage stage of high-salinity fluid SI; when $S_w \neq 0$ or $S_w = 0$, low-salinity fluid SI can be called the "osmosis-enhanced SI"; and we have found that "newly formed pores or microfractures" as well as reducing salinity can promote SI. This article presents a systematic study of SI of shale oil reservoirs under the influence of osmosis, which provide useful information for reservoir numerical simulation and development program design.



DOI: https://doi.org/10.1007/s40789-022-00516-x

CNN coal and rock recognition method based on hyperspectral data

Jianjian Yang, Boshen Chang, Yuchen Zhang, Wenjie Luo, Shirong Ge & Miao Wu

Abstract: Aiming at the problem of coal gangue identification in the current fully mechanized mining face and coal washing, this article proposed a convolution neural network (CNN) coal and rock identification method based on hyperspectral data. First, coal and rock spectrum data were collected by a near-infrared spectrometer, and then four methods were used to filter 120 sets of collected data: first-order differential (FD), second-order differential (SD), standard normal variable transformation (SNV), and multi-style smoothing. The coal and rock reflectance spectrum data were pre-processed to enhance the intensity of spectral reflectance and absorption characteristics, as well as effectively remove the spectral curve noise generated by instrument performance and environmental factors. A CNN model was constructed, and its advantages and disadvantages were judged based on the accuracy of the three parameter combinations (i.e., the learning rate, the number of feature extraction layers, and the dropout rate) to generate the best CNN classifier for the hyperspectral data for rock recognition. The experiments show that the recognition accuracy of the one-dimensional CNN model proposed in this paper reaches 94.6%. Verification of the advantages and effectiveness of the method were proposed in this article.

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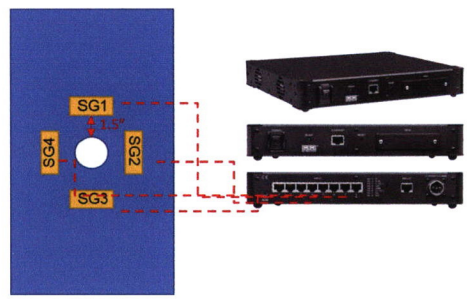
Laboratory investigation into the use of soundless chemical demolitions agents for the breakage of hard rock

Kelly-Meriam Habib, Isaac Vennes & Hani Mitri

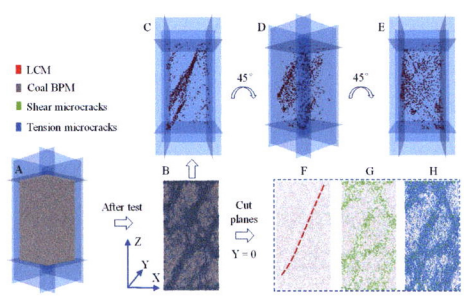


Abstract: The method of drilling and blasting with explosives is widely used in rock fragmentation applications in the mining industry for mine development and ore production. However, the use of explosives is associated with rigorous safety and environmental constraints as blasting creates toxic fumes, ground vibrations, and dust. This study is focused on the use of Soundless Chemical Demolition Agents (SCDA) as a more environmentally friendly method for rock breakage and a potential replacement of explosives. In this paper, the results of a series of experimental tests are reported to identify the effect of SCDA on hard rock breakage under no load and under uniaxial loading conditions. Stanstead granite prismatic specimens of 152.4 mm (6″) × 152.4–203.2 mm (6–8″) × 406.4 mm (16″) are used to test the influence of borehole size on the time to fracturing with SCDA borehole size of 25.4 mm (1″), 31.75 mm (1.25″) and 38.1 mm (1.5″). It is shown that the fracturing time decreases with increasing borehole size. It is also shown that specimens subjected to uniaxial compression of 5 MPa fracture as early as 7 h after SCDA mixing. A borehole spacing to borehole diameter ratio of 12.8 to 14.6 is suggested for practical applications.

DOI: https://doi.org/10.1007/s40789-022-00534-9

Triaxial compression behavior of large-scale jointed coal: a numerical study

Xiaoqing Wang & Fuqiang Gao



Abstract: Accurate estimation of the triaxial compression behavior of jointed coal is essential for coal mining. Few studies addressed the triaxial compression behavior of large-scale rock mass, especially with real joint geometry. We employed a numerical synthetic rock mass (SRM) method to study the triaxial compression behavior of jointed coal. Jointed-coal specimens were constructed based on in-situ joint measurements and microparameter calibration against laboratory experiments. A series of triaxial compression tests under different loading orientations and confining pressures were numerically performed to obtain joint and confining-pressure effects on the triaxial compression behavior and reveal the failure mechanism of jointed coal. Results suggest that the triaxial compression behavior of the jointed coal has strong joint and confining-pressure effects. Joints weaken the strength and elastic modulus, reduce the lateral deformation, and affect the geometries of the shear-rupture surface. An increase in the confining pressure causes the peak and residual strength increase significantly. With an increase in the confining pressure, the elastic modulus increases sharply at low confining pressure, the mechanical behavior transitions from brittleness to ductility, the failure mode transitions from shear-rupture surface to plastic flow, and the joint effect diminishes and even disappears. The jointed coal fails by means of a shear-rupture surface under triaxial compression loading with a confining pressure (which is not too high), and the geometries of the shear-rupture surface vary with the distribution of joints.

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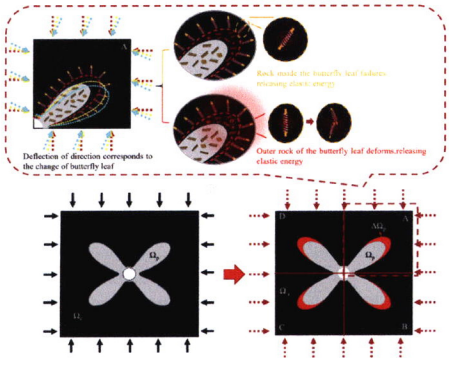
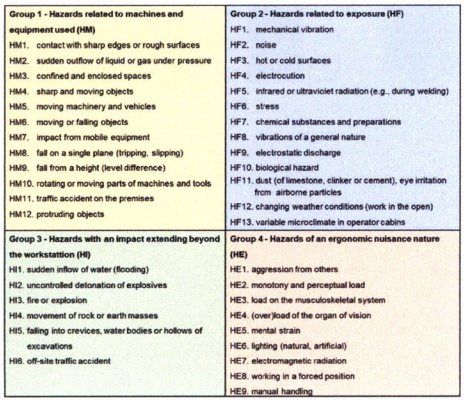


DOI: https://doi.org/10.1007/s40789-022-00521-0

Rockburst mechanism and the law of energy accumulation and release in mining roadway: a case study

Feng Du, Ji Ma, Xiaofei Guo, Tianfeng Wang, Xiaohang Dong, Jiashuo Li, Shulei He & Dilinaer Nuerjuma

Abstract: The rockburst dynamic disasters in the process of deep coal mining become more and more serious. Taking the rockburst occurred in the 23130 working face of Yuejin Coal Mine as the engineering background, we study the characteristics of mining stress field around roadway, the plastic failure morphological characteristics of surrounding rock and the accumulation/release law of elastic energy before and after burst. An analysis model quantitatively describing the physical process of rockburst in the mining roadway is established, and the calculation method of dynamic release of elastic energy in the physical process of rockburst is educed. The mechanism of rockburst in mining roadway is revealed. The results show that an "L-shaped" stress concentration zone is formed within 100 m of the 23130 working face, and the principal stress ratio of the surrounding rock of the transportation roadway is 2.59–4.26. The change of the direction of the maximum principal stress has a significant effect on the burst appearance characteristics. The failure strength of different sections of the mining roadway is characterized by the elastic energy release value. With the increase of the working face distance, the elastic energy released by burst failure and the expansion variation of failure boundary radius show a nonlinear variation law that tends to decrease steadily after sharp fluctuation. The closer to the working face, the higher the burst risk. At a distance of 10 m from the working surface, the maximum principal stress reaches its maximum value. The butterfly-shaped failure system generated by the surrounding rock of the roadway has energy self-sustainability, and the elastic energy released by the sudden expansion of the butterfly leaf is enough to cause a burst damage of 1.9 magnitude. This work could provide theoretical support for the prediction and prevention of rockburst.



Group 1 - Hazards related to machines and equipment used (HM)	Group 2 - Hazards related to exposure (HF)
HM1. contact with sharp edges or rough surfaces	HF1. mechanical vibration
HM2. sudden outflow of liquid or gas under pressure	HF2. noise
HM3. confined and enclosed spaces	HF3. hot or cold surfaces
HM4. sharp and moving objects	HF4. electrocution
HM5. moving machinery and vehicles	HF5. infrared or ultraviolet radiation (e.g., during welding)
HM6. moving or falling objects	HF6. stress
HM7. impact from mobile equipment	HF7. chemical substances and preparations
HM8. fall on a single plane (tripping, slipping)	HF8. vibrations of a general nature
HM9. fall from a height (level difference)	HF9. electrostatic discharge
HM10. rotating or moving parts of machines and tools	HF10. biological hazard
HM11. traffic accident on the premises	HF11. dust (of limestone, clinker or cement), eye irritation from airborne particles
HM12. protruding objects	HF12. changing weather conditions (work in the open)
	HF13. variable microclimate in operator cabins
Group 3 - Hazards with an impact extending beyond the workstattion (HI)	**Group 4 - Hazards of an ergonomic nuisance nature (HE)**
HI1. sudden inflow of water (flooding)	HE1. aggression from others
HI2. uncontrolled detonation of explosives	HE2. monotony and perceptual load
HI3. fire or explosion	HE3. load on the musculoskeletal system
HI4. movement of rock or earth masses	HE4. (over)load of the organ of vision
HI5. falling into crevices, water bodies or hollows of excavations	HE5. mental strain
HI6. off-site traffic accident	HE6. lighting (natural, artificial)
	HE7. electromagnetic radiation
	HE8. working in a forced position
	HE9. manual handling

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Occupational risk assessment based on employees' knowledge and awareness of hazards in mining

Michał Patyk & Dagmara Nowak-Senderowska

Abstract: Analyses and assessments of hazards occurring in work processes are carried out by teams, in which there is usually one representative of the personnel, as the embodiment of the active participation of employees in the assessment of occupational risks. This is why the article presents research on all employees' knowledge and awareness about risks in their work environment. The research was carried out in the form of an employee survey in one of the open-pit mines, at workstations dealing with the loading and transporting of excavated material. The survey included a list of 40 hazards divided into four groups: (1) hazards related to machines and equipment used, (2) hazards related to exposure, (3) hazards with an impact extending beyond the workstation and (4) hazards of an ergonomic nuisance nature, where employees were required to indicate which hazards apply to their workplaces and determine their level of significance, probability of occurrence and the scale of possible effects. In this way, a hierarchical identification of threats

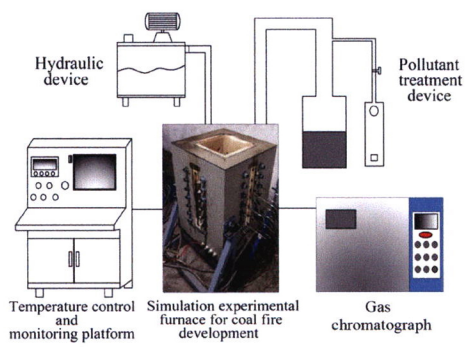
occurring at the analyzed workplaces was made, and the obtained results were used to determine the amount of occupational risk both for specific workstations and for the whole technological process. The measures of the magnitude of occupational risk obtained using the proposed method have showed that, according to the respondents, greatest risks at the workstation are associated with moving machines and vehicles and with mobile equipment. Equally important risks, which were often mentioned by employees, were those directly related to their health, i.e., related to ergonomic nuisance and exposure. Threats resulting from geological and mining conditions, considered typical for mining, were important for the surveyed miners but they were not the most important owing to proper prevention, good organization of work and high safety culture The active involvement of the crew in the process of assessing occupational hazards allowed to identify the significance of each hazard, in the opinion of the personnel working at various places and to use this ranking for determining occupational risk levels in the mining company concerned. The research has also outlined another goal to be achieved: a comparison of the relative significance of hazards identified by the employees and of the hazards listed in occupational risk assessment matrices used by mines.

DOI: https://doi.org/10.1007/s40789-022-00535-8

Semi-enclosed experimental system for coal spontaneous combustion for determining regional distribution of high-temperature zone of coal fire

Jingyu Zhao, Hanqi Ming, Tao Guo, Yuxuan Zhang, Jun Deng, Jiajia Song, Qiang Zeng & Chi-Min Shu

Abstract: Temperature variation and gas generation at different depths and positions in the coal combustion process were studied to determine the propagation and evolution of high temperature regions in the process of coal spontaneous combustion. This study selected coal samples from Mengcun, Shaanxi Province, People's Republic of China, and developed a semi-enclosed experimental system (furnace) for simulating coal combustion. The thermal mass loss of coal samples under various heating rates (5, 10, and 15 °C/min) was analyzed through thermogravimetric analysis, and the dynamic characteristics of the coal samples were analyzed; the reliability of the semi-enclosed experimental system was verified through the equal proportional method of fuzzy response. The results reveal that the high-temperature zone is distributed nonlinearly from the middle to the front end of the furnace, and the temperatures of points in this zone decreased gradually as the layer depth increased. The apparent activation energy of the coal samples during combustion first increased and then decreased as the conversion degree increased. Furthermore, the proportion of mass loss and the mass loss rate in the coal samples observed in the thermogravimetric experiment is consistent with that observed in the first and second stages of the experiment conducted using the semi-enclosed system. The research findings can provide a theoretical basis for the prevention and control of high-temperature zones in coal combustion.



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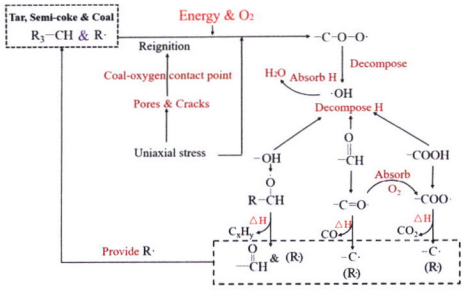

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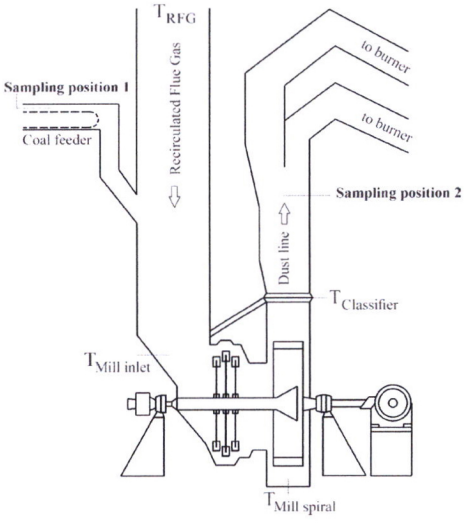
Effect mechanism of nitrogen injection into fire-sealed-zone on residual-coal re-ignition under stress in goaf

Yongliang Xu, Zejian Liu, Xinglin Wen, Lanyun Wang, Zhiguang Lv, Jindong Wu & Minjie Li

Abstract: Coal is the one of foundations of energy and economic structure in China, while the unsealing of coal mine fires would cause a great risk of coal re-ignition. In order to explore the influence of pressure-bearing state on the re-ignition characteristics for residual coal, the uniaxial compression equipped with a temperature-programmed device was built. The scanning electron microscope, synchronous thermal analyzer and Fourier transform infrared absorption spectrometer was applied to investigate the microscopic structure and thermal effect of the coal samples. Moreover, the microscopic effect of uniaxial stress on coal re-ignition is revealed, and the re-ignition mechanism is also obtained. As the uniaxial stress increasing, the number, depth and length of the fractures of the pre-treated coal increases. The application of uniaxial stress causes the thermal conductivity to change periodically, enhances the inhibition of injecting nitrogen on heat transfer and prolonges the duration of oxidation exothermic. The content of oxygen-containing functional groups has a high correlation with apparent activation energy, and coal samples at 6 MPa is more probability to re-ignite while the fire zone is unsealed. Uniaxial stress could control the re-ignition mechanism by changing the structure of fractures and pores. The side chains and functional groups of coal structure are easier to be broken by thermal-stress coupling. The higher the ·OH content, the more difficult coal samples would be re-ignited. The research results would lay a solid theoretical foundation for the safe unsealing of closed fire-areas underground, tighten the common bond between the actual industry and the experimental theory in closed fire-areas underground, and provide the theoretical guidance for coal re-ignition preventing.



DOI: https://doi.org/10.1007/s40789-022-00536-7

Thermal desorption of mercury from lignite in a high-temperature furnace and in power plant mills

Anne-Christin Kropp, Kathrin Gebauer & Michael Beckmann

Abstract: In this article, the binding forms of two lignite samples are determined by thermal desorption using a high-temperature furnace. Each mercury compound, such as $HgCl_2$, has a specific binding strength whose decomposition requires a certain thermal energy. Hence, the release of mercury from pure substances and lignite samples was analyzed in a high-temperature furnace. The released mercury is determined with a Mercury Vapor Monitor. The obtained characteristic temperature range and peak of the mercury release were compared between lignite samples and mercury pure substances. For the lignite samples investigated, the binding form of mercury was then identified as Humic Acid. These organic compounds vaporize at lower temperatures. About half of the mercury bound in the lignite was already released at 350 °C. Furthermore, the question arises whether mercury is already released during the grinding-drying process in the coal mill of a power plant. At two power plants, lignite samples were taken simultaneously at the feeder before entering the coal mill and at the dust line afterwards. The samples were analyzed for mercury concentration. The results show that up to one third of the mercury was already released in the coal mill. The vaporized mercury enters the combustion chamber detached from the lignite. The stated analysis methods and the results presented in this article contribute to the understanding of the mercury binding forms in lignite. It also shows the potential of thermal coal pretreatment as a favorable alternative mercury separation technology to others such as activated carbon dosing.

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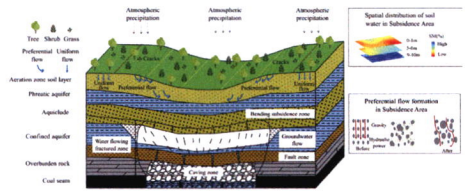
Spatial variability of soil moisture in a mining subsidence area of northwest China

Lu Bai, Yajing Wang, Kai Zhang, Yingming Yang, Kaikai Bao, Jiangang Zhao & Xiaonan Li



Abstract: The current study investigated the impact of coal mining on deep soil moisture from the perspective of the absolute value of soil moisture. A combined classical statistics and multi-dimensional geo-statistics approach was employed to analyze the temporal and spatial changes in soil moisture from 0 to 10 m in the mining face of the Nalin River No. 2 Mine in Northwest China from the perspective of spatial variability. The results of the study show that compared with the control area, the average value of soil moisture in 1- and 2-year subsidence areas decreased by 1.18% and 0.96%, respectively, whereas the coefficient of variation increased by 17.92% and 3.63%, respectively. Interpolation of soil moisture spatial distribution results showed that the spatial variability of soil moisture in the control area was less than that in the subsidence areas, and the spatial variability of soil moisture in the 2-year subsidence area was less than that in the 1-year subsidence area, indicating that mining increases the spatial variability of soil moisture and that the degree of spatial variability of soil moisture decreases as the subsidence enters the stable period. These results provide evidence for the mechanism by which coal mining subsidence affects soil moisture. Preferential flow caused by surface cracks, soil texture, the soil pore microstructure, and other factors in the coal mining subsidence area are the primary drivers of the increase in spatial variability of soil moisture.

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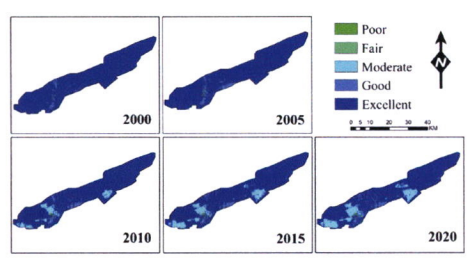
Surface coal mining impacts on land use change and ecological service value: a case study in Shengli coalfield, Inner Mongolia

Lijia Zhang, Xu Zhou, Yan Zhou, Ji Zhou, Jiwang Guo, Zihan Zhai, Yan Chen, Xiangyan Su, Lingxiao Ying, Liwei Wang & Ying Qiao



Abstract: Coal plays a crucial role in global economic development and remains the most common and widely distributed fossil fuel worldwide. As the world's largest developing country, China's mining and utilization of coal resources have contributed significantly to the country's rapid economic growth. Inner Mongolia is an ecologically fragile arid and semi-arid area of China. The exploitation of opencast mining has seriously hindered the sustainable use of regional land and the residents' well-being. Using ENVI-based remote sensing images from 2000, 2005, 2010, 2015, and 2020, this study employed a random forest algorithm to divide land utilization types into construction land, vegetation, cultivated land, bare land, and water areas and analyzed the characteristics of land use and ecosystem service value changes over the past 20 years. The results were as follows: (1) Construction land in the mining area changed minimally from 2000 to 2020; vegetation and water bodies showed a decreasing trend, whereas bare and cultivated lands showed an increasing trend. Bare land exhibited the largest change in area proportion and water bodies the smallest. (2) The total ecosystem service value of the mining area declined from 10.939 to 9.527 billion Yuan. Vegetation ecosystem service value was the highest, followed by cultivated land and water, with the bare land ecosystem service value the lowest. (3) On a spatial scale, the total ecosystem service value of the Shengli mining area decreased year by year, indicating that land use changes in the mining area do have an impact on ecosystem service value.

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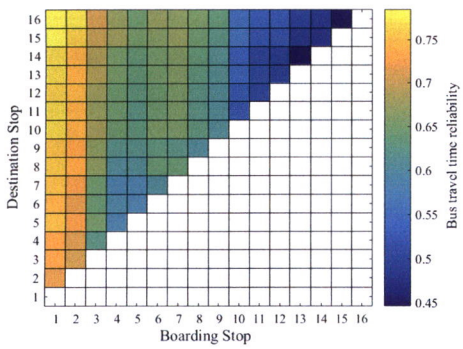
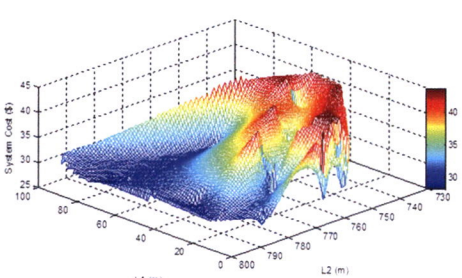


DOI: https://doi.org/10.1007/s40789-022-00544-7

Bus travel time reliability incorporating stop waiting time and in-vehicle travel time with AVL data

Zixu Zhuang, Zhanhong Cheng, Jia Yao, Jian Wang & Shi An

Abstract: Improving bus travel time reliability can attract more commuters to use bus transit, and therefore reduces the share of cars and alleviates traffic congestion. This paper formulates a new bus travel time reliability metric that jointly considers two stochastic processes: the in-stop waiting process and in-vehicle travel time process, and the bus travel time reliability function is calculated by the convolution of independent events' probabilities. The new reliability metric is defined as the probability when bus travel time is less than a certain threshold and can be used in both conditions with and without bus transfer. Next, Automatic Vehicle Location (AVL) data of the city of Harbin is used to demonstrate the applicability of the proposed method. Results show that factors such as weather, day of the week, departure time, travel distance, and the distance from the boarding stop to the bus departure station can significantly affect the travel time reliability. Then, a case with low bus departure frequency is analyzed to show the impact of travelers' arrival distribution on their bus travel time reliability. Further, it is demonstrated that the travel time reliabilities of two bus transfer schemes of the same Origin–Destination (O–D) pair can have significantly different patterns. Understanding the bus travel time reliability pattern of the alternative bus routes can help passengers to choose a more reliable bus route under different conditions. The proposed bus travel time reliability metric is tested to be sensitive to the effect of different factors and can be applied in bus route recommendation, bus service evaluation, and optimization.



DOI: https://doi.org/10.1007/s40789-022-00543-8

Individual variable speed limit trajectory planning considering stochastic arriving patterns

Qianwen Li & Handong Yao

Abstract: Connected vehicles enabled by communication technologies have the potential to improve traffic mobility and enhance roadway safety such that traffic information can be shared among vehicles and infrastructure. Fruitful speed advisory strategies have been proposed to smooth connected vehicle trajectories for better system performance with the help of different car-following models. Yet, there has been no such comparison about the impacts of various car-following models on the advisory strategies. Further, most of the existing studies consider a deterministic vehicle arriving pattern. The resulting model is easy to approach yet not realistic in representing realistic traffic patterns. This study proposes an Individual Variable Speed Limit (IVSL) trajectory planning problem at a signalized intersection and investigates the impacts of three popular car-following models on the IVSL. Both deterministic and stochastic IVSL models are formulated, and their performance is tested with numerical experiments. The results show that, compared to the benchmark (i.e., without speed control), the proposed IVSL strategy with a deterministic arriving pattern achieves significant improvements in both mobility and fuel efficiency across different traffic levels with all three car-following models. The improvement of the IVSL with the Gipps' model is the most remarkable. When the vehicle arriving patterns are stochastic, the IVSL improves travel time, fuel consumption, and system cost by 8.95%, 19.11%, and 11.37%, respectively, compared to the benchmark without speed control.

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