An Interdisciplinary Response to Mine Water Challenges - Sui, Sun & Wang (eds)
©2014 China University of Mining and Technology Press, Xuzhou, ISBN 978-7-5646-2437-8

Technical Status of Mine Water Control in China and Its Development Strategy

Shuning Dong [1,2], Hao Wang [1,2], Qisheng Liu [1,2] , Rui Chai[1]
1 Xi'an Research Institute of China Coal Technology & Engineering Group Corp., Xi'an, China, dongshuning@cctegxian.com, wanghao@cctegxian.com, chairui@cctegxian.com
2 Shaanxi Key Lab of Coal Mine Water Hazard Prevention and Control, Xi'an, China, liuqisheng@cctegxian.com

Abstract The aim of this study was to identify the problems of present water hazard control technology and equipment, as well as present some science and technology development countermeasures. In this paper, investigation of mine water disasters was conducted, the current situation of mine water prevention and control was analyzed, the basic theories and practical technology for mine water control were summarized, and some science and technology countermeasures were developed to prevent and control mine water disasters, which can be briefly summarized as studying basic theories, developing key technology and equipment, constructing research and development platform, and strengthening safety management.
Keywords technical status, mine water disaster, minewater control, development strategy

In China, under the effective supervision and management of State Administration of Coal Mine Safety, coal mine water disasters decline sharply. However, shallow coal resource is dried up gradually, so coal companies turn to deep coal resource. Generally, the deeper the coal mines locate, the more complex the hydrogeological condition is, and the harder water hazard prevention and control work is. In such conditions, large coal mine water inrush disasters still occur frequently in some coal mine areas. In order to control mine water hazard thoroughly, mine water researchers still have a long way to go. It is urgent to develop new science, technology and equipment, as well as strengthen the research of water hazard control mechanism.

Technical status and problems of mine water control in China

Technical status and problems of mine water hazard exploration in China

Geophysical exploration technology

Geophysical exploration technology can be divided into ground geophysical exploration technology and underground geophysical exploration technology.

At present, ground geophysical exploration technology includes 2D/3D seismic exploration, transient electromagnetics, high-density electrical method, direct current method, controlled-source audio-magnetotellurics, ground penetrating radar, rayleigh wave and interborehole fluoroscopy etc.

Three-dimensional seismic exploration is the most effective geophysical prospecting technology for high-resolution exploration of geological structures. It uses sound waves to form sharp three-dimensional images of underground formations. In China, it has been successfully used to detect the faults whose throw is less than 3 m. And it can also be used to prospect concealed geological structure and adverse geologic body. Ground electromagnetic method is especially effective for detecting underground water-bearing geologic body with low resistivity, such as flooded goaf and water-bearing sink hole.

However, this technology is limited severely by geological conditions. Under the conditions of long detection distance and accidented terrain, the detection precision of ground geophysical technology is relatively low. For example, with the increase of detection depth, the detection precision of ground geophysical exploration would be reduced obviously. In

addition, the detection precision is still not accurate enough to find out small faults and sink holes.

Underground geophysical exploration technology can be divided into two groups.The first group is electromagnetic wave detection technology, which includes radio wave perspective, transient electromagnetics, direct current method, high-density electrical method, ground penetrating radar, and audio frequency electric perspective, etc. The second group is elastic wave detection technology, which includes channel wave seismic, MSP (Mine Seismic Prospecting), microseismic monitoring, rayleigh wave exploration, multi-component seismic exploration, etc.

Among those methods, direct current method, transient electromagnetic, ground penetrating radar, Rayleigh wave exploration, and mine remote seismic method are applied widely and obtain good results in Chinese coal mines.

Although many kinds of technology and equipments for underground geophysical exploration make good effects, there are still some problems that need to be solved. For example, the basic theory research under the condition of non semi-infinite foundation and non infinite foundation is weak and there is serious electromagnetic interference, which result in interpretation ambiguity, failed reporting and misinformation.

Drilling technology

Drilling technology for coal mine water hazard control can be divided into two types, conventional rotary drilling and directional drilling technology, which can be applied under both ground and underground conditions. In recent years, accurate positioning technique, branch drilling technique, directional drilling technique and large diameter borehole drilling technique have made great progress. For example, directional drilling equipment came into use in 2008. Up to now, it has worked very well in China's coal mines. In the Hongliu coal mine, located in northwestern China, directional drilling technology was successfully used to explore underground water-bearing areas which were near the mining roadway. In addition, in the Zhaogu coal mine, located in central China, directional drilling technology was employed to drill boreholes effectively which were used for underground grouting.

However, both conventional rotary drilling technology and directional drilling technology are difficult to drill in the high pressure aquifers, as well as less effective when drilling in extremely hard(or soft) stratums.

Chemical exploration technology

Hydrogeochemical detection technology is an important means for mine water prevention and control. It has remarkable effect in discriminating water inrush source because it is a rapid, economic and practical method. Years of theory and practice show that the hydrochemical and isotope method are effective methods for detecting groundwater formation, occurrence conditions, distribution characteristics and migration regularity.

Conventional hydrochemical analysis methods mainly analyze the ion content, salinity, hardness, alkalinity, Ph and Eh value. Ion content analysis can be used to judge the condition of groundwater transportation, the strength of water exchange and hydraulic connection. Except for the conventional hydrochemical analysis methods, using the isotope analysis method can solve many problems about the groundwater seepage, such as, age determination of the groundwater; researching the origin and regularity of formation and distribution of the groundwater; tracing groundwater movement; determination of hydrogeological parameters; researching the source of the groundwater chemical composition. At present, the environmental isotopes used most widely include D(^{2}H), T(^{3}H), ^{18}O, and ^{13}C, ^{14}C.

However, some mining areas have not established the hydrochemical databases, which are very effective for judging the source of water inrush rapidly. In addition, present hydrogeochemical detection technology has non-ignorable error when dealing with water inrush problems of sink holes.

Technical status and problems of mine water hazard monitoring and early warning technology in China

Water hazard monitoring is the precondition of safe mining above or under water. In terms of monitoring environment, roof or floor aquifer monitoring can be divided into two groups, ground monitoring and underground monitoring; In terms of monitoring object, it can be divided into dynamic groundwater properties monitoring, and water inrush monitoring; in terms of monitoring conditions, it can be divided into monitoring under natural conditions and monitoring under mining conditions.

In China, a series of water inrush monitoring, data acquisition, data processing systems and related software have been developed. In addition, some new technology and equipment have been researched. Take mine water real time monitoring system for example, it is a distributed serial digital communication network system based on Controller Area Network (CAN) technique. The monitoring system includes three parts: monitoring center (mainframe computer, printer, network communication adapter, etc.), monitoring substation (sensors, data acquisition unit, network communication interface, etc.) and data transmission network (Dewu J et al. 2013).The monitoring items include water level, water pressure, water temperature, precipitation, mine water inflow, maintenance condition of mine water facilities, real time condition of mine drainage system. This system has been successfully used in the Jiaozuo, Pingdingshan, Yongcheng coal mine areas in China in recent years.

Fig.1 shows the roof water hazard monitoring and early warning system developed by Xi'an Research Institute, which was successfully applied in the undersea working faces of the Beizao coal mine in Longkou. Monitoring indexes of this monitoring system include water pressure, water quality, water temperature, and water inflow rate. Surface and underground boreholes were used to monitor water pressure, water temperature and water quality of target aquifers. Early warning thresholds of water quality indicators were determined by water matching tests.

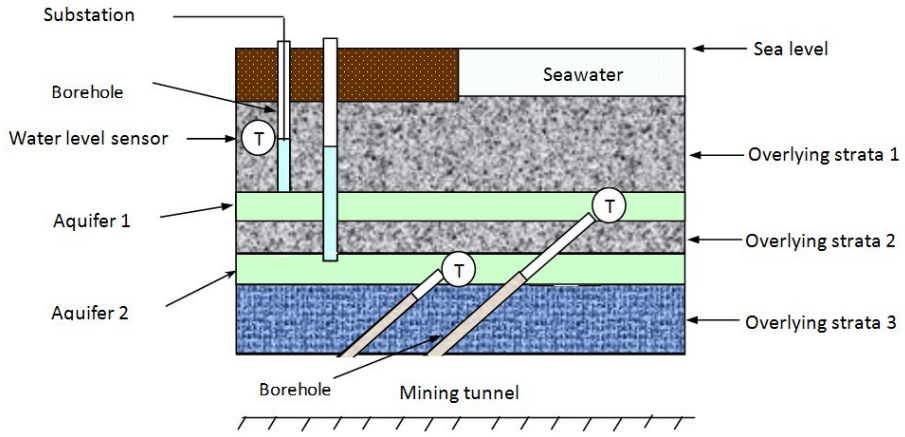

Fig.1 *Roof water hazard monitoring system*

However, there are some urgent problems that need to be solved. First, it is difficult to determine the threshold value of water hazard monitoring and early warning. Second, there is a long way to go to meet the practical demands for accuracy, validity and practicability of water hazard monitoring.

Technical status and problems of mine water hazard control technology in China

Coal mine water hazard control technology can be divided into two types, water hazard hidden danger control technology and post-disaster control technology.

The widely used water hazard hidden danger control technology includes coal floor grouting reinforcement and reconstruction, the shaft grouting, preliminary grouting for faults and sink holes, as well as the curtain grouting technology.

Post-disaster control technology includes comprehensive geophysical exploration of water inrush channels, branch borehole drilling and directional drilling technology, water-retaining wall construction technology and sink hole water stopper construction technology. Take sink hole water stopper construction technology for example, a sink hole water stopper is constructed successfully by grouting in a proper position to block the sink hole water inrush channel in the Dongpang coal mine (Shenghui N, et al. 2008). Grouting and monitoring boreholes were drilled with directional drilling technology to ensure designed trajectory. There are four grouting steps to construct a water stopper: regular grouting, pressure grouting, drainage grouting and reinforcement grouting. The effectiveness of water stopper can be evaluated by underground dewatering tests.

However, the present research on the regularity of diffusion and solidification of the grout under flowing water conditions is still insufficient. Furthermore, there is no systematic experimental study on the grouting technology under different hydrodynamic conditions.

Technical status and problems of mine water hazard emergency rescue technology in China

In recent years, the development of coal mine water hazard emergency rescue technology mainly focused on drainage technology with large submersible pump, rapid drilling technology, large diameter rescue borehole drilling technology and rapid grouting seal rescue technology, etc. Advanced rescue equipment, which performs very well in the rescue hole operation, include T series of vehicle-mounted mobile drilling rig from SCHRAMM company, RD series drilling rig from ATLAS company, RB series drilling rig from BAUER company and G series drilling rig from SOILMEC company, etc. As for Chinese rescue equipments, Xi 'an Research Institute of China Coal Technology & Engineering Group Corp developed the emergency rescue drilling rig whose function is closed to equipment made by famous international company.

However, some problem have not been solved effectively, such as, the communication between the ground crews and the underground trapped staff, ground large diameter rescue borehole drilling technology and ancillary facility.

Science and technology development countermeasures for coal mine water hazard prevention and control in China

Focusing on two key types of water hazards

First, in the terms of water source, it is urgent to take goaf water and limestone water as the key water source hazard. Second, as for water inrush channel, make permeable faults and sink holes as the key prevention and control channel. A large amount of work should be done to strengthen research on detection, monitoring, prediction and control of water hazard of goaf water, limestone water, faults water and sink hole water, which is on the basis of comprehensive water hazard prevention and control.

Strengthening two types of promotion and development technology for water hazard control

To strengthen the promotion and development of water hazard control technology, the first important point is to promote the existing technology and equipment which is advanced and well developed for water hazard prevention and control, in order to improve mine prevention and control ability comprehensively. The second point is to strengthen the prevention and control technology research of urgent need to develop, leading the development frontier of technology and equipment.

Adopting three science and technology development strategies of water hazard control

The first strategy is to develop basic theory deeply; the second one is to strengthen research and development of the key technology and equipment; the third one is to promote R&D platform construction.

Developing basic theory

The basic theories that need to be researched are as follows:
Study the basic theory of geophysical exploration for detecting goaf water, with the emphasis on the geophysical basis characteristics and the comprehensive exploration theory of goaf water;

Research the mechanism of water inrush from coal floor, especially for deep coal seam which is under high water pressure and high ground stress, in order to provide fundamental basis for water inrush risk assessment.

Strengthening research and development of the key technology and equipment for water hazard control

For water hazard detection technology and equipment, the key is to develop the technology and equipment for fine detection of goaf water, permeable faults and sink hole, as well as detection and dewatering of high pressure aquifer.

For water hazard monitoring and early warning technology and equipment, further study should be done to research the real-time monitoring and early warning technology, with emphasis on the research of threshold value of water hazard monitoring and early warning.

For water hazard evaluation and prediction technology, influence of the key water inrush factors, such as coal floor damage depth, lift height of fractured zone and thickness of coal floor aquitard, should be comprehensive analyzed based on the deeply study of mechanism of water inrush from coal floor.

For water hazard control technology and equipment, utilization and grouting reconstruction of the top of Ordovician limestone technology should be researched, and effective grouting process and device should be developed.

For water hazard emergency rescue technology and equipment, rapid drilling of ground large diameter borehole technology and ancillary facility should be developed, in order to provide support for scientific, timely and effective rescue of mine water disaster.

Promoting scientific and technical platform construction

In order to effectively promote technological innovation of the coal mine water hazards prevention and control and share the professional resources socially, the coal mine water hazards prevention and control engineering technology center should be established by the professional institutions as soon as possible. National key laboratories and supporting facilities, which cover water inrush mechanism research, grouting technology and process research and hydrochemical analyses, should be constructed. In addition, some typical coal

mine should be supported to speed up the construction of water hazard prevention and control engineering demonstration base.

Conclusions and Suggestions

In this paper, the features of coal mine water disasters in China were illustrated, and the problems of present water hazard control technology and equipments were identified.

Although technology and equipments for water hazard exploration, monitoring, emergency rescue and control have made great effects, there are still some problems that need to be solved.

For exploration technology and equipments, the basic theory research under the condition of non semi-infinite foundation and non infinite foundation is weak and there is serious electromagnetic interference which result in interpretation ambiguity, failed reporting and misinformation; conventional rotary drilling technology and directional drilling technology are difficult to drill in the high pressure aquifers, as well as less effective when drilling in extremely hard(or soft) stratums; present hydrogeochemical detection technology has non-ignorable error when dealing with water inrush problems of sink holes.

For monitoring technology and equipments, it is difficult to determine the threshold value of water hazard monitoring and early warning, so it is hard to meet the practical demands for accuracy, validity and practicability of water hazard monitoring.

For control technology and equipments, the present research on the regularity of diffusion and solidification of the grout under flowing water conditions is still insufficient. Furthermore, there is no systematic experimental study on the grouting technology under different hydrodynamic conditions.

In order to prevent coal mine water disasters effectively, some measures should be carried out on time, such as making proper laws and policies, providing project support, offering fund guarantee and developing new industry standards. These measures can make coal mine safety situation improved steadily. In addition, the support of research projects on the coal mine water hazards prevention and control, comprehensive utilization of water resources, as well as water environment protection, should be strengthened.

References

Dewu J, Yingfeng L, Zaibin L, et al. (2013) New progress of study on major water inrush disaster prevention and control technology in coal mine. Coal Science and Technology 41(1): 25-29

Shenghui N, Qinming J, Xiaoshan G, et al. (2008) Construction technique of groundwater-preventing piston in Karst flow sink hole. Coal Geology and Exploration 36(4): 29-33

Shuning D, Dewu J, Hong F (2008) Practical technology and equipment for mine water prevention and control. Coal Science and Technology 36(3): 8-11

Zhijun SH, Shuning D, Ningping Y, et al. (2011) The underground directional drilling technology and equipment for kilometre deep borehole with MWD in coalmine. Procedia Earth and Planetary Science 3: 17-22