The progress of the mine water prevention and control on basic principles in China

Wu Qiang, Liu Shouqiang, Zeng Yifan

State Research Center of Mine Water Prevention and Control, China University of Mine & Technology, Beijing 100083, China,
wuq@cumtb.edu.cn

Abstract

Water disasters occur during coal mine construction and production in China and account for many of the nation's mine disasters and casualties. However, China has made major strides in preventing these major water inrush disasters during the last decades. Based on the comprehensive summary of the theory and method, application technology, practical engineering and technical standard currently used in coal mines of China, this paper analyzed systematically the latest research progresses and achievements on the basic theory, hydrogeology (supplement) exploration, advanced detection and monitoring as well as early warning of the water disaster, prevention and control technologies in the field of the mine water prevention and control as well as utilization.

Key words: prevention and control of mine water; utilization of mine water; research progress; China

Introduction

China ranks the third around the world in geological reserves of coal resources, but is the first coal-producing country from the beginning of 21st century. China' land is composed of multiple tectonic plates reworked by sequential geological tectonic movements. As a result, the geological structures are very complex. China is one of the countries in which the most serious mine water disasters occur. According to statistics by Chinese State Administration of Production Safety Supervision and Management, the water inrush disasters are second only to the gas explosion disasters in coal mines in the serious and extraordinarily serious accident categories. Mine water inrush disasters not only cause heavy casualties, but also are the most serious of mine accidents in terms of economic losses, accident emergency rescue, and mine restoration effort. In addition, the water disasters occur widely. All the mine enterprises, especially underground mines or underground excavation engineering works, generally face with these problems. So the social impact of water disasters is serious, and the attention degree is high in China and abroad.

With the exhaustion of shallow and upper group coal resources, water disasters in mining deep and lower group coal resources are increasingly serious because of progressively complex mine water-filling hydrogeological conditions, additional control factors over water disasters, and complicated water inrush mechanism and type. Many mines not only face with roof water inrush threat from gob water because of the water pooling in the shallow closed mines, but also face with the floor water inrush threat from high confined groundwater in carbonate rock. Meanwhile, gas explosion, gas outburst and water inrush coexist in the coal seam, i.e., the working face and development face are in the environment of "roof threat, floor inrush, and middle burst".

Mine water inrush disaster control continues to keep decline and continuous improvement in the case of strong growth production and increasing mining intensity recently. The national coal production increased from nearly 1 billion t in 2000 to 3.7 billion t in 2013. The output turned over 3.7 times in 13 years. At the same time, the accident total number and total death toll induced by water inrush disasters in China have decreased to 21 and 89, respectively in 2013 from 104 and 351, respectively in 2000, falling by almost 80% and 75%, respectively (Fig.1).

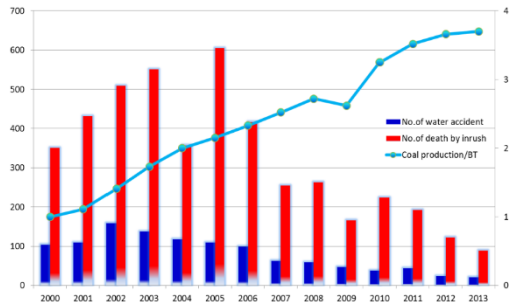

Figure 1 *Relationship of national coal production and water inrush disasters*

According to the surveys and statistics by State Administration of Coal Mine Safety in 2012, the national mine water discharge was up to 7.17 billion m^3/a in recent years; there were 61 mines in which the normal water inflow was more than 1,000 m^3/h; and mine water resources utilization rate increased year after year. These data showed that China had made great progress and research results in recent years in the field of water inrush prevention and control and resource utilization[6-8]. But water disaster prevention and control is still a daunting task and face with many challenges because of various hydrogeological condition type and complex structure and changeable hidden water inrush factors and various mechanism, especially with the large-scale development of deep level resources. Mine water inrush disasters control and resource utilization will be still one of the important research topics in safety production and scientific mining in China.

1. The new basic principle of water prevention and control

The research results have improved the basic principle of water prevention and control, put forward the new basic principle that is summarized with 16 Chinese words and its corresponding comprehensive measures, i.e., prevention, plugging, dewatering, drainage, and interception. The previous basic principle used in China for mine water inrush prevention and control was summarized with "8 Chinese words", i.e., "when in doubt, exploration must be done in advance; excavation occurs only after the exploration." The "8-words" principle has played a positive role in recent years, as the state emphasized the great importance to the safety production and implemented a series of policies and punishment regulations. The mine enterprises improved safety production consciousness and management, and miners also paid attention to the safety.

If suspicious symptoms of water disaster had been found at the scene, engineering technicians and professional workers will immediately investigate the situations and dewater in advance if needed. The doubtful position or hidden danger of water inrushes must be identified before mining. The questions are how to find the doubtful position? How to judge water disasters risk in advance? These are much more in demand to resolve the important issue for mine enterprise and field engineering technician at present. To answer these questions, *Coal Mine Water Prevention and Control Regulation* article 3 presents the new "16-words" principle, i.e., "first forecasting; when in doubt, exploration must be done; excavation occurs only after exploration; control should be in place before mining." First of all, we should find doubtful position of disasters through scientific forecasting methods, followed with detection and discharge of water in advance. We then excavate after detection and water discharge. We finally mine coals after any necessary control measures are in place. The "16-words" basic principle forms a complete technical route. In correspondence with the "16-words" principle, *Coal Mine Water Prevention and Control Regulation* article 3 puts forward five comprehensive prevention measures in prevention, plugging, dewatering, drainage, and interception.

2. The new mine hydrogeology classification

The achievements have supplemented and improved the basic principle of mine hydrogeology classification and the main influence factors, put forward the mine hydrogeology classification based on scientific methods and analysis of the new water disasters features in China in recent years. The purpose of mine hydrogeology classification is to analyze the mine hydrogeological

condition, direct hydrogeological supplement exploration and water disasters prevention and control. Due to high proportion of coal resources under water disasters threat and various water hazards types caused by complex mine hydrogeological condition, the hydrogeology classification plays an important role in safety production. Considering the wide distribution of gob water with fuzzy scope, location and shape, and the continuous water inrush disasters induced by the gob water in recent years, at the same time considering the factors (whether water inrush occurred or not in the process of construction, production and water inflow) are associated with the complex degree of mine water filling hydrogeological condition, the mine hydrogeology classification incorporated two new factors of gob water distribution and mine water inflow based on the original four factors.

3. The new safety requirements and technical standards of mining under water and surroundings

With the increase in mining intensity and exhaustion of shallow level resources in China, development of the deep level resources is inevitable. In addition, the coal resources that are not be commonly developed under or around of the sea, lakes, rivers, reservoirs, gob water area and strong rich water aquifer and other large water body in the past are increasingly exploited. First of all, all kinds of water sources which threaten safety production should be dewatered in advance. Mining can be done only after the water is drained and hidden dangers are eliminated. If dewatering is not feasible and the coal seams to be mined are inclined or gently inclined, the regulation *Coal Pillars Setting and Coal Mining Regulations of Building, Water, Railway and Main Shaft* must be followed. We must understand the water filling hydrogeological conditions, compile special mining design, and organize relevant technical discussion in order to determine the safety and reliability of water prevention coal (rock) column and make safety precautions. Mining can occur only after approval by the chief manager of the coal mining enterprise. In addition, dynamic monitoring should be in place. Producing should stop and withdraw of miners must be in order immediately if abnormal situations are discovered. Due to lack of theories and engineering technology problems induced by mining such as caving mechanism, the caving development regularity and height, caving control, mining of steep coal seams is still a task to be solved effectively and is strictly prohibited in China.

4. The platform construction of mine water filling 3D visualization analysis of hydrogeological conditions

Traditional water filling hydrogeology analysis method was based on point, line, plane, section, etc. By forecasting, we understood and cognized the 2D space of mine water filling hydrogeological condition. These methods could not reflect and depict the complex 3D water filling condition and phenomenon, lacking dynamic space-time processing and analysis ability, and having big limitations. The 3D hydrogeology visualization modeling and simulation analysis method solve these problems to some extent, can provide a uniform 3D display channel, and support comprehensive and integrated display as well as management of data such as the hydrogeological exploration, test and underground exploration and mining engineering. The method can also analyze arbitrarily stratigraphic profile, query a variety of hydrogeological parameters, and realize stress-strain analysis, groundwater flow simulation, water inrush risk evaluation, water inflow forecast and optimization of water prevention and control design, etc. The 3D water filling hydrogeology visualization analysis platform will become an effective tool for the ground and underground hydrogeological exploration and test data processing, physical concept model analysis of water filling condition, water flow simulation evaluation, water disaster prediction, water prevention and control plan formulation, etc.

5. Mine water disaster forecast theory and the different disaster forecast evaluation methods

Hydrogeology exploration provides a very important geological information for mine structure, the relations of main coal seam and sedimentary structure, the water filling source, water channel and gob. But the local discrete information is limited, and using the information directly to analyze water disaster is very preliminary, and unable to give full consideration to the potential value contained in the hydrogeological exploration results. If we use the advanced scientific evaluation method and model to analyze, simulate and process the original information, the results can be evaluated and predicted in zoning characteristics and water hazards risk levels from the roof, floor, gob and geologic structure in the process of mine production. The prediction results can be effectively used to make prevention measures for different types of mine water disaster. We presented the comprehensive evaluation method

of the vulnerability index method which considers more factors than those based on water inrush coefficient method for floor water inrush. For roof water disaster, we put forward three maps - double prediction method which can solve the key technical problems of roof water filling source, channel, and the intensity at the same time.

6. Rapid recognition technique of water inrush

Any water inrush points of underground mining engineering happened in most cases by accepting different types of water supply such as atmospheric precipitation, surface water, groundwater, or gob water and discharging into underground mines. Due to different types of water source in the process of formation, runoff and discharge influenced and interfered by different geological environment and human factors, the hydrogeochemical characteristics, water temperature and water level (pressure) of water source are all different. These large number of sample points collected at the scene in different aspects and the various parameter such as water chemistry, water temperature and water pressure (level) can provide an extremely important water source information and form the foundation database. Mathematical models can then be established for rapid recognition of underground mine water inrush supply source. Inputs of water pressure (level), the measured water temperature and water chemistry analysis results in underground water inrush point into the mathematical models will help quickly and accurately recognize the water supply sources of the water inrush point. The main used equipment with better application effect at present in China include intrinsically safe YSYF6 mine water inrush source rapid recognition instrument researched and developed jointly by Wuhan Long Sheng An Ke Technology Co., Ltd. and China University of Mine & Technology (Beijing), and HA-W600 mine filling water source rapid recognition instrument researched and developed jointly by Beijing Hua An Ao Te Science and Technology Co., Ltd.

7. Conclusion

This paper systematically analyzes the latest research progress and achievements in China including the current basic theory of mine water prevention and control, the hydrogeology exploration and water disasters forecast, the advanced detection and the monitoring and early warning, main prevention and control technology of mine water disasters.

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