A New Dimension in Coal Mine Safety: ExploSpot, Active Explosion Suppression Technology

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Abstract

With the continuous innovations in technology and the industrialization of mining processes, modern mining operations are greatly improved. The use of high powered machines and automatic mining equipment is one of the methods of enhancing the mine’s efficiency, but it has also brought new challenges for mining safety, especially the risk of gas/coal dust explosions. The traditional methods of explosion elimination and suppression can obviously not provide effective protection anymore. The HS mine active suppression system, derived from military technology and based on intelligent high speed activation can provide an effective and practical method to eliminate the devastating effects of a gas/coal explosion in a mining operation. This is a major breakthrough in gas/coal dust explosions prevention technology. This technology provides a new, effective and professional solution which enables a modern mine to manage the increased risks of a gas/coal dust explosion.

1. Introduction

China is a country that has more coal deposits than natural oil. The proved coal reserves accounts for 30% of that of the world. China ranks second in the world for the recoverable amount of coal. It is ranked first in coal production and second in coal export volumes. As a non-renewable source, coal is the most important basic energy resource for the country. The coal industry maintains the economic lifeline of the country and support the sustained rapid development of the national economy. In the research paper, Development Strategy for Sustainable Energy of China, more than 20 academicians agreed that coal will account for not less than 50% in the production and consumption of non-renewable energy by 2050. It is therefore expected that the leading position of coal in the national economy must be stable and sustainable. Because of its un-substitutability, the coal dominated energy consumption pattern in China will not change in the foreseeable future. Ninety five percent (95%) of coal mining operations in China are sub terrain operations.

Accidents normally occurred during mining production when there is a coal and gas outburst, a rock burst, spontaneous coal combustion, water flooding, roof falls, excessive temperatures, etc. Gas explosions, according to statistical data from coal mine accidents reports, are the most severe and with the highest loss
of human life. An increase of gas and coal dust explosions is recorded in recent years. In 2004 alone, a total 3641 coal mine accidents were recorded, with a total death toll of 6027. 492 accidents were caused by gas explosions. This contributes to 31.5% of all fatalities in the coal mine industry. In 32 of these accidents the fatalities were more than 100 persons.

Since the founding of People’s Republic of China, more than 20 accidents, where the fatalities were more than 100 occurred. The death toll from major disasters is almost 5000. Among the 20, 19 accidents are caused by gas explosion, gas and coal dust explosion, coal dust explosion and coal and gas outburst with a death toll of 3223. This represents 90.4% of all accidents and 93.26% of all fatalities across China. It is clear that gas and coal dust explosion disasters cause enormous loss of life and property. The effective prevention for gas and coal dust explosions is one of the major issues to ensure sustainable coal production levels in a safe and productive coal mine.

From the above it is obvious that the biggest threat for a coal mine is gas and coal dust explosions. This, not only limits the mine’s production capability, but in a larger extent leads enormous economic loss and in doing so, preventing the coal production’s role for ensuring the rapid development of national economy. It also has negative social influences and harms the international profile of the country.

2. Safety challenges in a modern coal mine

With the advancements in technology and during industrialization processes, mechanized mining has become more widely used in modern mines and the trend is to move towards more high-power machines and automation of the mining process.

With the use of these increased numbers of modern mining equipment, not only have production efficiencies increased, but also deeper coal seam and more complex geological formations are mined. With this increased intensity and complex mining operations, new safety challenges must be addressed because the main threat for safety in the mine did not disappear, it actually got worse. This threat in a mine is the “killer” gas, methane, and it will continue to be a threat if nothing is done about it.

The coal industry has recognized that modern mining operations pose new challenges in mine safety. High volume coal produced by high-powered mechanical mining machines has caused a sharp increase of methane gas emissions and coal dust. At the same time, it is inevitable that mechanical equipment will produce higher levels of frictional ignitions that will lead to increased dangers during the mining operation. This hidden danger in mining cannot be solved by the traditional gas explosion elimination methods. If the three dangerous factors (fuel, oxygen and ignition source) are combined, a serious gas or coal dust explosion will occur.

The traditional gas explosion prevention and control techniques are called explosion elimination methods. When the explosion elimination methods have shortcomings, additional methods have to be implemented for effective suppression and thus solving the hidden dangers brought by mechanical mining methods. Based on a gas and coal dust explosion risk analysis of a mine, an effective explosion suppression and isolation methods need to be implemented to achieve the following aims:

• Suppress explosion and prevent the explosion from spreading
• Reduce the formation of toxic and harmful gasses
• Reduce the formation of the destructive pressure front
• Stop the temperature rise above human tolerances
• Save life and mine property

The flame and explosion suppression technology, currently used in the mining environment, is based on a variety of first generation water bags, developed in the last century, but with some improvements. The operational principle of passive suppression system is that uses the dynamics of the explosion’s pressure wave to activate it. Because there is a time difference between pressure wave and flame front, the pressure wave is used activate the water bag, thus, firstly to release the flame elimination agents by forming a suppression barrier and secondly, to limit the amount of airborne coal dust. The explosion will be suppressed and it will not propagate any further. All the passive suppression systems are limited using this
type of mechanism. The capacity and effect is inadequate and is affected by different mining environments and human factors in the application of it. Summarizing the results of the world’s main research institutions, the passive barrier’s common limitations include the following:

Table 1. Features of passive suppression system

| Application                                      | Test | Features of passive suppression system                                      |
|-------------------------------------------------|------|---------------------------------------------------------------------------|
| The heading face where there is a high concentration of workers | ×    | Passive barrier’s trigger pressure must exceed 30KPA                      |
| 5-12m from the high risk point                  | ×    | Passive barrier’s trigger pressure must exceed 30KPA                      |
| 30m from the protection point (area)             | ×    | Passive barrier’s trigger pressure must exceed 30KPA                      |
| 60m from the protection point (area)             | √ -  | Possible to achieve in an extreme ideal environment                      |
| 100m from the protection point (area)            | √    | Evaluated by coal dust explosion test                                    |
| 120m from the protection point (area)            | √    | Evaluated by coal dust explosion test                                    |
| More than 120m from the protection point (area)  | √ -  | Flameproof bag is inefficient; some of barriers may be effective.         |
| Protection of a mine worker’s life in the region.| ×    | The destructive high-energy pressure wave will spread across the region. |
| Limiting toxic and harmful gas generation        | ×    | Cannot restrict the formation of large-scale toxic and harmful gas.       |
| Limiting the generation destructive pressure wave| ×    | The destructive high-energy pressure wave will spread across the region. |
| Protect the assets and equipment of the mine.    | √ -  | Pressure wave still causes extensive damage.                            |
| Emergency extinguishing function                 | ×    | Needs the explosion’s pressure wave to trigger                          |
| Successful suppression cases and reports         | ×    | No reports, all the accidents have caused serious damage.                |
| Installation area                                |      | Bags are spread over a large area                                         |
| Amount of suppressant (flame suppressing agent) |     | Large amounts, depending on the different installation models.           |
| Mobile and convenient                            | Fixed| Difficult to move, removal and installation costly                        |
| Asset/expendable                                 | Expendable | Limited life, not reusable.                             |

Note:
1. “√” = Qualified
2. “×” = Failed qualification
3. “√ -” = Partially qualified
The above legend is used throughout this document.

3. The HS Active suppression system

After realizing the inherent deficiency of passive explosion system, most international research institutions have, in the 70 years of the last century, began to explore the possibility of alternative technologies and directions. In 1985 reports by M. Faber and E.W. Scholl for a diverse source automatic explosion suppression system in mines was delivered in Sydney. In the report the first ideas were put forward and the technical parameters for an active suppression technology was shaped. Later on, most countries and research institutions have taken notice of it and develop the technical research and relevant
standards based on the concepts of this report.

In 1990 CSIR conducted a successful initial test on an active mine suppression system. The system was based on proven military technology. Late in 1994, after an explosion accident at the Middelbult mine, an ad hoc committee, authorized by President of South Africa, requested that research institutions from different countries and companies must be officially invited to participate in R&D and demonstration tests with regard to active suppression systems and products. In 2001, after 7 years of research, development and tests the ExploSpot active suppression system, produced by HS Design Engineering Pty, Ltd., has became the first active suppression product supplier qualified by GMRA in South Africa. They are also the only supplier to date.

What is active suppression?

The active suppression technology is the high speed detection, analysis and suppression of a gas and coal dust explosion. The main functions of HS active suppression system are:

- Suppression of the gas or coal dust explosion at mining face (suppression).
- Preventing the gas or coal dust explosion from spreading through the mine (isolation).

Special test facilities were built and used to verify the actual efficiency of HS Active Explosion Suppression System. GMRA and CSIR have tested and assessed the different applications of the system. Spain, America, Australia, China and a third party research institutes have conducted more than one thousand tests under different situations, conditions and projects. The same conclusion was drawn from those tests; HS Active Explosion Suppression System can effectively suppress gas and coal dust explosion for the different required environments. (SIMRAC report 2004-0214).

With the correct installation of a HS Active Explosion Suppression System, the system can detect and suppress an initial explosion. By suppressing the explosion it can; effectively control the volume of toxic gases, prevent the generation of a destructive pressure wave, limit the temperature rise beyond human tolerance, and eventually save the personnel and property of mine.

Application features of HS Active Explosion Suppression System as follows:

Table 2. Features of Active Explosion Suppression System

| Application                                      | Test | Features of passive suppression system                              |
|-------------------------------------------------|------|---------------------------------------------------------------------|
| The heading face where there is a high concentration of workers | ✓    | Evaluated by gas and coal dust explosion tests                      |
| 5-12m from the high risk point                  | ✓    | Evaluated by gas and coal dust explosion tests                      |
| 30m from the protection point(area)             | ✓    | Evaluated by gas and coal dust explosion tests                      |
| 60m from the protection point(area)             | ✓    | Evaluated by gas and coal dust explosion tests                      |
| 100m from the protection point(area)            | ✓    | Evaluated by gas and coal dust explosion tests                      |
| 120m from the protection point(area)            | ✓    | Evaluated by gas and coal dust explosion tests                      |
| More than 120m from the protection point(area)  | ✓    | Evaluated, but not recommend                                       |
| Protection of a mine worker’s life in the region. | ✓    | Achievable by restricting the explosion                             |
| Limiting toxic and harmful gas generation       | ✓    | Achievable by restricting the explosion                             |
| Limiting the generation destructive pressure wave | ✓    | Achievable by restricting the explosion                             |
| Protect the assets and equipment of the mine.   | ✓    | It protects the installation point and beyond                      |
| Emergency extinguishing function                | ✓    | Manual trigger available                                            |
Successful suppression cases and reports ✓

Four successful suppressed explosions recorded. No casualties reported.

Installation area
Small area
System are installed close to risk areas

Amount of suppressant
8kg/m²
Small amount

Mobile and convenient
Movable
Can mounted on mining equipment and machines and also as standalone movable or portable equipment

Asset/expendable Asset
Reusable modules

Comparing the active explosion suppression system with the passive barrier system, not only are the initial defects of the passive barriers overcome but with the correct installation and application of the active suppression system, coal mine disasters can be prevented with the reduction in loss of life of the coal mine worker and the mine’s assets.

Table 3 Comparison of the Active Explosion Suppression System versus Passive Explosion Isolation Equipment

| Application | Features of HS active explosion suppression system | Features of passive explosion isolation equipment |
|-------------|---------------------------------------------------|--------------------------------------------------|
| The heading face where there is a high intensity of workers | ✓ | × |
| 5-12m from the high risk point | ✓ | × |
| 30m from the protection point(area) | ✓ | × |
| 60m from the protection point(area) | ✓ | ✓ - |
| 100m from the protection point(area) | ✓ | ✓ |
| 120m from the protection point(area) | ✓ | ✓ |
| More than 120m from the protection point(area) | ✓ | ✓ - |
| Protection of a mine worker’s life in the region. | ✓ | × |
| Limiting toxic and harmful gas generation | ✓ | × |
| Limiting the generation destructive pressure wave | ✓ | × |
| Protect the assets and equipment of the mine. | ✓ | ✓ - |
| Emergency extinguishing function | ✓ | × |
| Successful suppression cases and reports | ✓ | × |
| Installation area | Small area | Large area |
| Amount of suppressant (flame suppress agents) | 8kg/m² | 80kg/m² |
| Mobile and convenient | Movable | Fixed |
| Asset/expendable | Asset | Consumables |

4. Application of the active explosion suppression system
HS active explosion suppression system for the mining environment is an ultra high speed active explosion suppression device specifically developed for gas or coal dust explosion. Because of its unique technical properties, actual explosion suppression is achieved in the true sense of the word and thus has made breakthroughs in the gas and coal dust explosion prevention technology.

4.1 Intelligent identification

The advanced sensing and signal identification technology can accurately and quickly evaluate the explosion signal. It can distinguish between an explosion and flame signal and any other source and thus making it immune to all known underground false signal sources.

4.2 Ultra-high speed activation

The advanced ultra-high speed activation arrangement has the world’s fastest response speed and it can open the suppression agent’s release mechanism within 2 milliseconds.

4.3 Fully automatic explosion suppression.

The advanced automatic control technology can automatically detect, trigger and record data. It does not require any human intervention for its normal functions. The built-in black box automatic record and saves system parameters and data.

4.4 Programmed self-test

The advanced integrated self-test function provides real time analysis of the system’s integrity and functionality.

4.5 Modularized design

Using modular building blocks, reliable design and manufacturing are achieved and also provide flexibility and convenience in any underground mining installation.

4.6 Unit product

HS products have 3 major systems models, machine-mounted systems, long wall system and roadway barrier systems. Installation of these systems will be according to the different mining operation requirements and explosion suppression requirements. The modular product, which is highly integrated, enables the customer to use the product with different combinations and for different operations to optimize the desired suppression effect.

For the HS active explosion suppression system to effectively perform its function, the following three aspects should be considered during installation. This is according to the suppression system’s technical features and after investigations of the operational conditions of coal mines in China.

- **Stand-alone explosion suppression system.** Regional protection system should be placed and be divided into main suppression and assisted suppression in high risk areas, such as the heading face. The systems for the main explosion suppression area, such as machine-mounted system and long wall system, are mainly used to actively suppress an explosion and to prevent it from spreading. The assisted explosion suppression system, such as a roadway barrier system that will be installed in the heading face, is mainly used as a barrier to isolate the explosion and prevent it from spreading. Position protection system can also be installed at other high risk points, such as coal bunkers, transfer points and distribution points. The explosion suppression system can also be connected to the mine’s monitoring system.

- **System interlink group.** An interlink group is created when connecting explosion suppression systems together using special cables. Long wall systems and roadway barrier systems in the same barrier area should be interlinked. The interlinking of long wall systems are intelligent and activation one or more
systems will be done according to the initial explosion point in the coal face. By interlinking roadway barrier systems and simultaneously activate two or more system can provide optimal explosion suppression.

- **Manual emergency activation.** HS active explosion suppression system is equipped with emergency activation interface. The system can manually be triggered to extinguish the fire if its energy is not enough to automatically trigger the system or if the fire cannot be controlled with handheld fire extinguishers.

5. **System certification**

In 2001, HS Active Suppression System was certified by GMRA in South Africa, and then certified by Spanish, America, Germany, China and other independent third parties. The system is used successively by the well known mining companies, such as the Anglo American Group, South Africa SASOL Group, etc. The HS active suppression system passed the standardization certification of JOY Company of South Africa and is included as one of their standard parts. When HS active suppression system was introduced to China by Jincheng City, Shanxi, it has passed China National Safety Certification and has been officially installed in some mines in Jincheng.

6. **Conclusions**

Technical equipment, for the modern mine who needs to continually improve its productivity and at the same time be responsible for its production safety, must be developed. High priority must be given to the safety challenge and the hidden risks during coal face development. HS Active Explosion Suppression System is the best solution to make up for the current shortcomings of explosion elimination methods. The Active Explosion Suppression System is an important component of modern mine safety.

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