Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2025, 12(3):43-47**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Current Status and Development Trend of Gas Extraction Drilling and Sealing Technology

ShuoWei Lv

Henan Polytechnic University, Jiaozuo 454003, China

Abstract: Mine gas is one of the main factors seriously threatening the safety of coal mine production, but also a kind of high-quality energy with a longer life than coal mining, the most fundamental measure to deal with underground gas is extraction, and when using drilling to extract gas, the sealing method and sealing quality are the decisive factors restricting the extraction effect. The key to hole sealing technology is to determine the reasonable hole sealing depth and length, select appropriate hole sealing materials and hole sealing equipment. In recent years, the use of "two blocks and one injection" pressure grouting hole sealing technology can effectively improve the sealing effect, improve the gas extraction rate, and reduce the risk of gas outburst.

Keywords: gas; extraction; sealing material; hole sealing equipment; two plugging and one injection

1. Introduction

China, the world's largest coal producer, faces increasing energy demands due to rapid economic growth. Coal will remain a dominant energy source to power national development in the foreseeable future. Under the "new normal" economic conditions, advancing the safe, stable, and sustainable development of coal—a foundational energy industry—is crucial for implementing national energy strategies [1].

Chinese coal seams, formed under unique geological conditions, are characterized by high gas content, strong adsorption, low permeability, and "three highs and one low" features: high gas content, high gas pressure, high ground stress, and low permeability [2]. The permeability of coal seams, a critical factor affecting gas extraction, ranges between0.1–0.001×10−3 μm in most Chinese coal seams 2–3 orders of magnitude lower than those in the U.S. and Australia. Coal and gas outbursts, among the most severe hazards in coal mining, cause significant damage to personnel, equipment, and society [3]. Gas-related disasters, including outbursts and explosions, correlate strongly with gas content: higher gas content increases outburst risks As shallow coal resources deplete, mining depths increase, exposing coal seams to high ground stress, gas pressure, and geothermal conditions. These complexities escalate the frequency and intensity of gas outbursts during deep mining. Thus, mitigating coal and gas outbursts during extraction has become a global research focus. Concurrently, coalbed methane (CBM), a byproduct of coal mining and a major methane source, has gained attention for its dual role in enhancing mine safety, reducing greenhouse gas emissions, and minimizing gas-related disasters. [4].

2. Current Research on Coal Mine Sealing Methods and Equipment

In the 1980s, Germany and Japan widely adopted polyurethane sealing technology, complemented by pneumatic mixing pumps. In the 1990s, Germany's Ruhr coal district developed expansive cement mixtures with up to 20% expansion rates, while Russia's Donbas mines utilized hydraulic expandable sealers, rubber sealers, and friction-based devices. The U.S. employed cement with mechanical systems, and the U.K. used resin and rubber ring sealers. Over decades, global efforts have focused on adapting sealing techniques to diverse geological conditions. Current mainstream technologies include clay sealing, cement mortar sealing, polyurethane sealing, mechanical sealers, and the "two plugs and one injection" pressurized grouting method [5-7]:

1. Clay Sealing

Early Chinese coal mines manually sealed boreholes using clay. The process involves inserting a pressure-measurement tube into the borehole, compacting clay columns (0.5 m each) with wooden plugs, and sealing the final 1 m with cement mortar (Figure 1). Advantages include simplicity, material availability, and low cost [8].

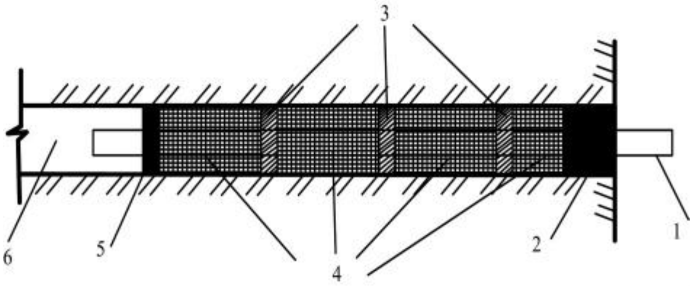


Figure 1: Clay Sealing

1- Pressure-measurement tube; 2- Cement mortar; 3- Wooden plug; 4- Clay; 5- Retaining plate; 6- Borehole

2. Cement Mortar Sealing

Cement mortar, mixed with specific cement grades and fine sand, replaced clay due to its inefficiency. However, shrinkage cracks formed in low-angle boreholes. Adding expansive gypsum mitigated this issue. Pre-mixed mortar is pressurized into the borehole via compressed air until outflow occurs (Figure 2). Manual methods, limited to 5 m, were replaced by pneumatic (up to 5 m) and grout pump methods (exceeding 20 m). Advantages include cost-effectiveness and simplicity [9-13]

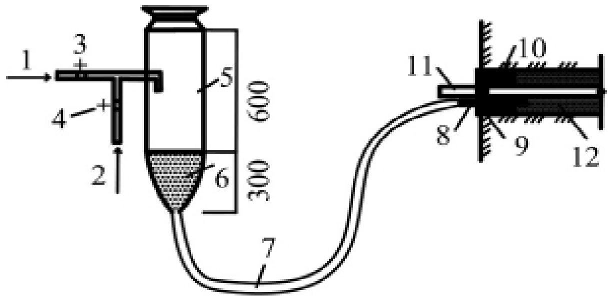
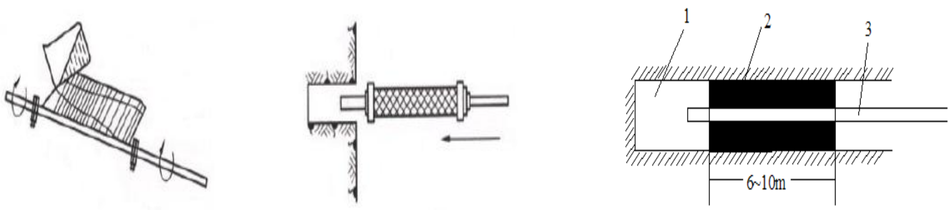


Figure 2: Pneumatic cement mortar sealing

1- Air pipe; 2- Water pipe; 3,4- Valves; 5- Grout tank; 6- Cement mortar; 7- Hose; 8- Grout pipe; 9- Wooden plug; 10- Polyurethane; 11- Pressure-measurement tube; 12- Borehole

3. Polyurethane Sealing

Polyurethane, developed in Germany in the 19th century, involves mixing black (polyol polyether) and white (polyisocyanate) components. The mixture expands radially upon injection, filling fractures in the coal around the borehole (Figure 3). Advantages include high expansion ratio, simplicity, and stability under pressure [14-17]



(a) (b) (c)

Figure 3: Polyurethane sealing

(c) 1- Borehole; 2- Polyurethane sealing segment; 3- Pressure-measurement tube

4. Rapid Sealer Sealing

Rapid sealers utilize mechanical force to expand rubber capsules against the borehole wall (Figure 4). Adjustable handles enable adaptability to varying borehole diameters. Advantages include speed, reusability, and ease of operation [18,19].

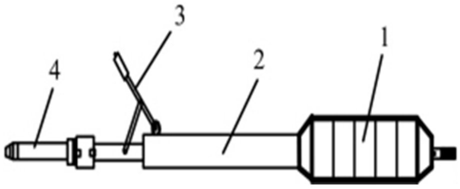


Figure 4: Rapid sealer

1- Capsule; 2- Transmission rod; 3- Handle; 4- Pressure-measurement tube

5. Mechanical Elastic Sealer Sealing

Elastic sealers, such as spiral-expanding ring and elastic ball-string types (Figures 5 and 6), rely on external force to expand rubber elements. Upon force removal, the elements retract for reuse.

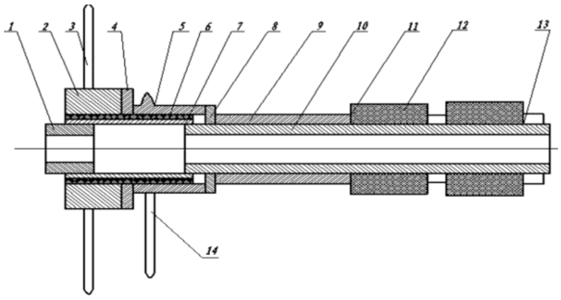


Figure 5: Spiral-expanding ring sealer

1.Connector; 2. Nut; 3. Handle; 4. Gasket; 5. Locating pin; 6. Casing; 7. Screw rod; 8. Force-transfer pad; 9. Outer sleeve; 10. Inner tube; 11. Tray; 12. Rubber barrel; 13. Locknut; 14. Handle

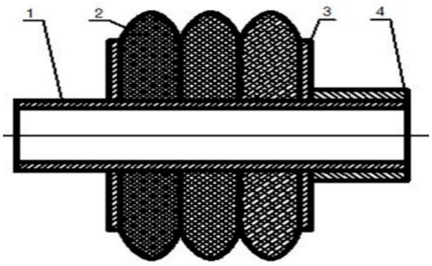


Figure 6: Elastic ball-string sealer

1- Inner sleeve; 2- Rubber balls; 3- Compression plate; 4- Compression sleeve

6. Two Plugs and One Injection" Pressurized Grouting

This method seals both ends of the borehole with polyurethane bags. After curing, pressurized grout is injected between the plugs to fill fractures (Figure 7). Professor Sun Yuning's bag-grouting method, an early form of this technology, uses inflatable bags to isolate the grouting zone. Advantages include enhanced airtightness and reduced gas leakage [20-27].

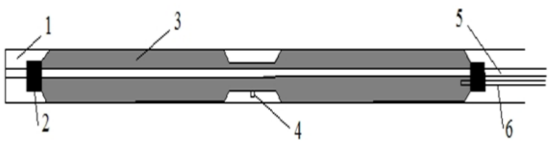


Figure 7: Bag-grouting sealing principle

1- Borehole; 2- Plastic plug; 3- Composite bag; 4- Grout outlet; 5- Pressure-measurement tube; 6- Grout pipe

3. Current Research on Sealing Materials

Sealing materials are categorized into chemical (e.g., polyurethane) and non-chemical (e.g., cement, clay) grouts. Chemical grouts, though effective, are costly and environmentally hazardous. Inorganic grouts are economical and durable but require improvements in curing time and crack penetration [29-33].

4. Future Development Trends

As mining depths and intensities increase, gas emission anomalies necessitate advanced sealing technologies. Current challenges include inadequate studies on initial sealing positions under rock creep effects, suboptimal material selection, incomplete fracture sealing, and improper sealing lengths. Recent innovations include.

Tang Jie’s pressure-preserving grouting device, integrating grout, return, and gas extraction pipes to eliminate "leakage triangles" [34]

Wu Peiwu et al.’s bag-type screened-tube pressurized sealing, improving gas concentration and extraction rates [35]

Xu Pengfei’s polyurethane-nonhardening paste composite sealing, achieving stable gas concentrations above 50% in fractured coal zones [36]

References

[1]. Tao Mingwen. Analysis of China’s Coal Industry Development Prospects[J]. Journal of Changchun University of Science and Technology (Higher Education Edition), 4(01):13-14.

[2]. Zhu Liyuan, Pan Yishan, Li Zhonghua, et al. Mechanism of Compound Disasters Involving Rockburst and Gas Outburst in Deep Mines[J]. Journal of China Coal Society,2018,43(11):3042-3050.

[3]. Jin Hongwei. Experimental and Mechanistic Analysis of Coal and Gas Outburst Processes[J]. Journal of China Coal Society, 2012, 37(S1): 98-103.

[4]. Sun Haitao, Wen Guangcai, Sun Dongling. Surface Well Gas Extraction Technology in Coal Mining Areas[M]. Beijing: China Coal Industry Publishing House，2017.

[5]. Zhou Hongchao. Study on Borehole Stability in Coal Seam Gas Extraction[D]. 2007.3-4.

[6]. CAO Shugang，LI Yong，LIU Yanbao.Effectiveness analysis of methane-drainage by deep-hole controlled pre-splitting blasting for preventing coal and gas outburst.Journal Of Coal Science & Engineering (China)，2009，15(2): 166-170.

[7]. CHENXuexi, MAShangquan, LIANGWei. Development of digital gas pressure determination instrument in coal seam. Proceedings of the 2008 International Symposium on Satety Science and Technology，September 24-27，2008，1624-1627.

[8]. Chen Xuexi, Ma Shangquan, Liang Wei. Development of Digital Gas Pressure Determination Instrument in Coal Seam[C]. Proceedings of the 2008 International Symposium on Safety Science and Technology，2005(1):26- 27.

[9]. Liu Di. Analysis of Grouting Sealing Technology in Coal Seam Gas Pressure Measurement[J]. Science and Education Information，2007(11):29-30.

[10]. Meng Fanlong, Jiang Chenglin, Zhao Wenbin. Analysis of Grouting Sealing for Fractures Around Boreholes in Coal Seam Gas Pressure Measurement[J]. Coal Mine Safety，2010(01): 87-90.

[11]. Zhao Zhengjun, Guo Shengjun. Development of KFB Mine Cement Slurry Sealing Pump[J]. Mining Safety & Environmental Protection,1999(2):19-20.

[12]. ZHAO Zheng- jun,GUO Sheng- jun.Development of KFB hole-sealing pump with cement and condensed slurry in mine[J]. Mining Safety & Environment al Protection,1999(2):19-20.

[13]. Wang Zhaofeng, Wu Wei. Analysis of Main Borehole Sealing Methods for Coal Mine Gas Extraction[J]. Coal Science and Technology，2014(11):29-30.

[14]. Chen Jie, Jin Longzhe. Study on Improving Gas Extraction Efficiency via Polyurethane Sealing[J]. Coal Engineering;2003(08):47-49.

[15]. Yang Hongmin, Wang Zhenya, Liu Jun. Rapid Clay-Polyurethane Sealing Technology for In-Seam Gas Pressure Measurement[J]. Coal Mine Safety, 2012，43(9):63-64.

[16]. Gao Mingsong. Segmented Pressure Grouting Technology Using Polyurethane-Cement Slurry[J]. Energy Technology and Management, 2011, (1):51-53.
[17]. Wang Daqing, Xing Xiang, Xu Xuefu. Application of Polyurethane Grouting Sealing Technology in Gas Extraction from Soft Coal Seams[J]. Coal Mine Safety，2001，37(9):89-91.
[18]. Wang Xiangyang, Wei Wei, Zhao Xuebing. Development and Application of KFQ-I Rapid Sealer[J]. Coal Science and Technology，2007, (3): 76-77.
[19]. Fan Fuheng. Development and Application of Rapid Sealer for Shallow Gas Extraction in Working Faces[J]. Coal Mining, 2006,11(4):89-90.
[20]. Huang Xinye, Jiang Chenglin. Experimental Study on Enhancing Gas Extraction Efficiency via Pressurized Sealing[J]. Coal Mine Safety, 2011,42(9):1-4.
[21]. Wang Fakai, Jiang Chenglin, Gong Yanwei, et al. Application of Double-Casing Pressurized Grouting in Gas Pressure Measurement[J]. Coal Mine Safety, 2010, (9):6-8.
[22]. Wei Fengqing, Yan Liuqiang, Zhang Xiangyang, et al. Experimental Study on Segmented Pressurized Sealing for In-Seam Gas Pressure Measurement[J]. Coal Engineering, 2011. (6):85-87.
[23]. Zhai Guohong, Jiang Chenglin, Wang Fakai. Gas Pressure Measurement Based on High-Pressure Grouting and Capsule Pressure-Adhesive Sealing[J]. Coal Science and Technology, 2010，38(5):47-49.
[24]. Zhang Fuwang, Fan Fuheng, Qin Ruxiang. Application of Bag-Type Two-Plugs-One-Injection Sealing Device in Gas Extraction from Bedding Boreholes[J]. Coal Engineering, 2013，（11）:57-59.
[25]. Pan Feng. Comparative Analysis of Gas Drainage Effects Between Bag Grouting and Polyurethane Sealing[J]. Coal Mine Safety, 2010，（9）:177-179.
[26]. Huang Xinye, Jiang Chenglin. Research on Pressurized Sealing Technology for Gas Extraction Boreholes in Coal Seams[J]. Coal Science and Technology, 2011.39(10):46-48.
[27]. Liu Chun, Song Xiaolin, Zhou Fubao, et al. Application of Directional Pressurized Grouting Sealing Technology in Bide Coal Mine[J]. Coal Mine Safety,2011.39(4):105-108.
[28]. Sun Yuning. Bag Grouting Sealing Device and Method[P]. China Patent: E21B33/138; E21F7/00, 2007.10.10.
[29]. Guan Xuemao. Research on Ultra-Fine High-Performance Grouting Cement[D]. Wuhan: Wuhan University of Technology, 2002,10,5-7.
[30]. Hao Zhiyong. Study on Material Composite Technology and Its Application in Borehole Sealing[D]. Xuzhou: China University of Mining and Technology, 2010,4-5,11-29.
[31]. Dong Jianjun, Yin Zuofang. Labor and Environmental Protection in Chemical Grouting Construction[C]. 8th Chemical Grouting Conference, 2002：248-251.
[32]. Wen Dijiang, et al. Principles of Composite Materials[M]. Wuhan: Wuhan University of Technology Press, 1998.11.
[33]. Wanghua Sui,Jinyuan Liu,Wei Hu,et al,Experimental investigation on sealing efficiency of chemical grouting in rock fracture with flowing water[J]. Tunnelling and Underground Space Technology,2015,(50):239-249.
[34]. Tang Jie. Research on Novel Pressure-Preserving Sealing Technology for Gas Extraction Boreholes[J]. Western Exploration Engineering,2022,34(09).
[35]. Wu Peiwu, Zhu Yafei, Zhao Bo. Experimental Application of Bag-Type Screened-Tube Pressurized Sealing Technology in Gas Extraction[J]. Coal Technology, 2022.10.038.
[36]. Xu Pengfei. Optimization of Sealing Technology for Large-Diameter Gas Extraction Boreholes in Malan Coal Mine[J]. Shandong Coal Science and Technology,2022,40(07).