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Failure analysis of borehole liners in soft coal seam for gas drainage

Liu Chun [a], Zhou Fubao [a,b,*], Yang Kangkang [a], Xiao Xiang [a], Liu Yingke [a,b]

[a] Faculty of Safety Engineering, China University of Mining & Technology (CUMT), Xuzhou, Jiangsu 221116, PR China
[b] State Key Laboratory of Coal Resources and Safe Ming, China University of Mining & Technology, Xuzhou, Jiangsu 221116, PR China

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ABSTRACT

In this paper, loads acting on the liner in inserting installation, drainage lifetime and recycling operation were analyzed. Texts on axial deformation, radial compressive deformation and shear deformation properties of the liner were carried out by the universal testing machine. The correlation between the test results and the different loads was discussed. The influences of sieve opening density and diameter on the liner mechanical properties were investigated. Furthermore, the microstructures of tensile deformation, compressive deformation and shear deformation were observed by scanning electron microscope (SEM). Our results are practically useful for the structure design of production liners to improve their mechanical properties. First, in the liner installation, the application of PP liner and PE liner is a top priority in boreholes with large curvature owing to their perfect bending stiffness. Second, during the drainage lifetime, the PP liner can offer a wonderful performance on radial deformation against the borehole collapse. Third, if the liner recycling is required, it is not encouraged to apply the PE liner due to its poor performance on tensile strength and shear strength. Fourth, the increase of sieve density (from 0/m to 10/m) only has an obvious influence on the tensile strength of liner and it is feasible for the efficient recycling to decrease sieve opening density partly. Finally, it is found that the surface of all materials after torsional deformation is worse than that after compressive deformation and after tensile deformation, indicating that shear failure is the key threat to liners.

1. Introduction

Coal seams across China are rich in methane, of which 50% are highly gassy and 44% are in danger of gas and coal outburst [1]. Consequently, the death rate per million-ton coal caused by mine gas accidents remains high, and gas has always been the main threat to mine safety. Currently, the mining seams are located on the deep level and the mining depth has reached over 1000 m in many mines in China. Especially in the next 10 years, the mining depth will have a sharp increase with the growth rate of 20 m per year [2]. As a result, the gas emission of coal mines will surge, and the mines will be confronted by the threat of methane [3]. In view of this situation, the National Coal Mine Safety Supervision Bureau of China enacted the law "Provisions of the Prevention of Coal and Gas Outburst" to prevent the outburst accidents in 2012. This law highlighted

* Corresponding author at: Faculty of Safety Engineering, China University of Mining & Technology (CUMT), Xuzhou, Jiangsu 221116, PR China. Tel./fax: + 86 516 83995053.
E-mail address: zfbcumt@gmail.com (F. Zhou).

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the necessity of regional methane control measures by mining protective coal seam or regional methane pre-extraction. The most commonly applied methane control solution, especially in high in-place gas content coal beds, is drilling methane drainage boreholes into the panel area prior to longwall mining to reduce the methane content of the coal bed. These boreholes can be vertical or horizontal boreholes drilled from the surface, or in-seam horizontal boreholes drilled from the underground entries [4]. On the other hand, an overwhelming majority of coal seams in Chinese coal mines took shape over a period of Carboniferous–Permian. As a consequence, the coal went through a number of strong tectonic movements and the original cracks in the coal mass were destroyed. The coal changed into a soft and construction-complex medium [5]. These soft coal seams are mainly distributed in Henan, Anhui, Guizhou, Sichuan, Yunnan and Hunan provinces of China, the coal-bed methane (CBM) reserve of which is 5.6073 trillion cubic meters in total, accounting for 39.2% of that of the whole country (Fig. 1).

From the perspective of gas disaster prevention and coal bed methane recovery, drilling boreholes into the soft coal seam prior to longwall mining to reduce the methane content of the coal bed is necessary. But the stability of boreholes is of critical importance because coal is a weaker material than sandstones and limestones so that the stress concentration around the boreholes may cause boreholes to fail easily, especially boreholes drilled in soft coal seam. In addition, the stresses created by mining activities in the coal can induce additional stresses and displacements in the formations surrounding the boreholes, which can lead to borehole collapse. These situations are more severe when the boreholes are completed open-holes [6,7].

Many scholars have carried out a wealth of studies on the prevention of borehole collapse in coal seam. Keim et al. obtained exploration borehole data from an undeveloped coal bed methane field in China's Qinshui Basin [8]. The stability of Pitchfork and Pinnate horizontal wells was analyzed based on their potential for catastrophic wellbore failure at well junctions and producing well branches. Mitigating the risk of borehole collapse could be accomplished by inserting liners within boreholes. The operability of lining Pitchfork and Pinnate patterns was discussed, and a conclusion was drawn that Pinnate pattern poses were more difficulty with respect to liners than Pitchfork patterns. Yet, risk can be offset in Pinnate patterns by lining the main lateral. Gentis analyzed the wellbore stability of horizontal coalbed methane wells in the Mist Mountain Formation, SE British Columbia, Canada [9]. The research indicated that a pre-perforated or slotted production liner should be inserted immediately following drilling in order to keep borehole stable. If the well collapses without a liner, the length of the wellbore beyond the collapsed region is lost, which will have a major impact on gas production and economic cost. The studies of Yao focused on the instability mechanism of boreholes in weak coal seam, which proposed that boreholes in weak structural seam could be more stable once the coal surrounding boreholes were strengthened or the linings were utilized in horizontal holes [10].

Till now, there exists very little information pertaining to perforated linings in horizontal coal bed methane boreholes in the literature. Although the success of liner installation has been noted in San Juan Basin, the utilized liner type, size and strength associated with its failure character are still unknown [8]. Motivated by this point, detailed investigations about the failures of the liners of different materials, as well as different sizes, are presented in this paper.

2. Background of the incident

Polyethylene (PE) liners have been in widespread use for gas drainage in the tenth coal mine of Pingdingshan Tianan Coal Mining Co. in Henan province of China. From the gas monitoring figures could we find that there were sudden drops of the

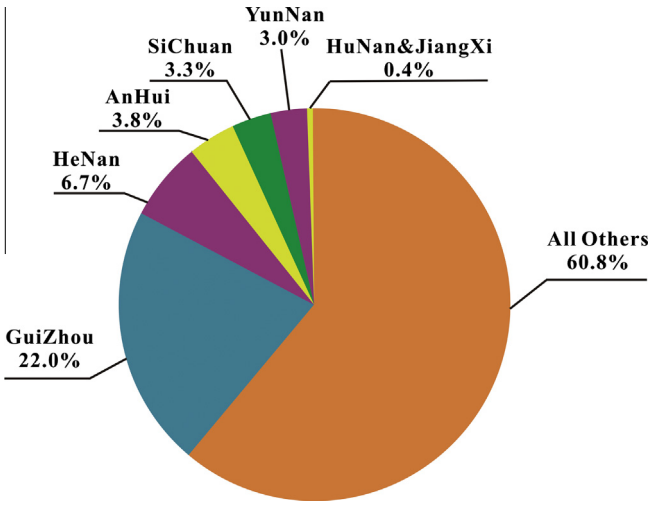

Fig. 1. The soft CBM reserves distribution in provinces of China.