Improving methane extraction ratio in highly gassy coal seam group by increasing longwall panel width

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Abstract

Coal mine methane (CMM) extraction is widely practiced in Chinese coal mines as a strategy to enhance coal mine safety and diversify energy resources. One of the main issues with current CMM extraction technologies is low methane extraction ratios. This is particularly the case in mining highly gassy coal seam group. To address the issue, this paper introduces a practical approach to improve the methane extraction ratio by increasing longwall (LW) panel width. The results of a field trial in Yangquan show that the methane extraction ratio increases by 45\% and coal production rate increases by 30\% with an increased LW panel width.

Keywords: coal mine methane; highly gassy multi coal seams; methane extraction ratio; overlying roadway

1. Introduction

The development of coalbed methane (CBM) has brought about a new energy boom throughout the world. In the United States, Canada, and Australia, CBM has attained commercial success. It is predicted that CBM will contribute as much as 25\% to the production of natural gas by 2020 in the United States\cite{1}.

China has the third largest CBM resource in the world\cite{2}. However, the majority of the CBM resource identified in China is adsorbed in coal seams of high grade metamorphism, low in-situ permeability, and low methane saturation, which significantly restrict CBM production by means of surface wells used successfully in other countries. Relevant literature review\cite{3} reveals that there are only about five CBM-bearing regions in China which have qualified or have a potential for commercial CBM developments.

China is the largest coal producing country in the world and has more than 20,000 underground coal mines. Extensive coal mining has resulted in a significant increase in strata permeability and methane desorption from the strata. In 2007, a total volume of extracted methane was 4.74 Bm³, consisting of 4.4 Bm³ from CMM and only 0.34 Bm³ from CBM surface extraction\cite{4}. This data shows that developing CMM is undoubtedly a very important part of methane development in China. One of the main issues in current CMM extraction in China is a low methane extraction ratio. Peng\cite{5} reported that the CMM extraction ratio was only 24\% on average in the Chinese coal...
mines. This is particularly the case in mining highly gassy multi seams.

Yangquan Coal Group (YCC) is a famous producer of anthracite in China. It is a large mining district of highly gassy multi coal seams. The panel width in this district was normally between 180 and 190 m. In this paper, a new method with increasing panel width to improve integrated CMM and coal extraction was discussed. The results from a field trial indicated that the CMM extraction ratio was increased by 45% and coal production rate was increased by 30% with an increased panel width.

2. Analysis of improving CMM extraction in Yangquan coal district

2.1. The general panel layout and methane extraction system

The No.3 mine of YCC extracts coal from seams of #15, #3, and #12. There are mainly 5 gassy coal seams (#3, #5, #8, #11 and #13) and 3 limestone strata (K2, K3, K4) overlying the mining seam #15 and are rich in methane. The generalized parameters of the methane reservoir are shown in Table 1 and its composition is shown in Fig. 1(c). The #15 seam is about 7 m thick and is extracted with a LW Top Coal Caving (LTCC) method.

Table 1. Generalized parameters of overlying coal seams of #15 seam

<table>
<thead>
<tr>
<th>Methane reservoirs</th>
<th>Thickness (m)</th>
<th>Distance above coal #15 (m)</th>
<th>In-situ methane content (m^3 t^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#13</td>
<td>0.15</td>
<td>51</td>
<td>17.787</td>
</tr>
<tr>
<td>#12</td>
<td>1.2</td>
<td>55</td>
<td>14.75</td>
</tr>
<tr>
<td>#11</td>
<td>0.3</td>
<td>64</td>
<td>15.64</td>
</tr>
<tr>
<td>#8’</td>
<td>0.45</td>
<td>92</td>
<td>21.65</td>
</tr>
<tr>
<td>#8</td>
<td>1.03</td>
<td>95</td>
<td>21.65</td>
</tr>
<tr>
<td>#5</td>
<td>0.35</td>
<td>128</td>
<td>18.27</td>
</tr>
<tr>
<td>#3</td>
<td>1.81</td>
<td>140</td>
<td>17.28</td>
</tr>
<tr>
<td>K2, K3, K4 limestone strata</td>
<td>3~64</td>
<td></td>
<td>Empirical methane emission rate is 25 m^3 min^-1 in normal panels^6</td>
</tr>
</tbody>
</table>

2.2. Analysis of methods to improve CMM extraction ratio

The general panel layout of #15 seam is shown in Fig. 1. In the panel, apart from one maingate and one tailgate developed in #15 seam for the normal production, two extra roadways were excavated for the purpose of methane control. One of such roadways was excavated in the top section of #15 seam and about 30 m offside the panel tailgate inside the panel and the other roadway was excavated at between 50 and 60 m above #15 seam and about 50 m offside the panel tailgate to extract methane released from the overlying coal seams during panel production. This system has been proven to be an effective in methane control and is widely used in YCC.

Fig. 1. (a) plan view of panel layout of #15 seam; (b) cross-section A-A of panel layout of #15 seam (c) cross-section B-B of panel layout of #15 seam

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The principle for CMM extraction by an overlying roadway is shown in Fig. 2. The fracture system, induced by coal mining, acts as flow paths for desorbed CMM to flow into the roadway. Generally, the lower part of the fracture zone contributes a high gas flow but low methane concentration CMM, whereas the upper part contributes a low gas flow but high methane concentration CMM. The height of the fractured zone plays an important role in the range of the CMM extraction. The height of the fractured zone induced by the normal panels in YCC is between 8 and 20 times of the mining thickness and the upper boundary of the zone generally lies just beneath #3 coal seam [6].

Since the overlying roadway is effective in methane emission into the mining coal face, the range of the CMM extraction can be tried to include the seams such as seam #3 in the bedding zone, as shown in Fig. 2. By taking into considerations of the factors affecting size and dimension of the fractured zone, a new design with an increased panel width was tried in YCC to increase the integrated extraction of coal and CMM.

3. Field trial

A field trial was undertaken in the panel K8206 in the No.3 mine. The panel width was increased to 252 m from a normal width of 180 m and the overburden depth was around 650 m. The surrounding mining condition of K8206 is shown in Fig. 3. It was the first panel in a new mining area. The mining status of the overlying #3 coal seam was different along the panel direction. It can be divided into 3 different zones. In zone I the overlying coal seams were unmined, in zone II there was a preparation panel in coal seam #3 and in zone ?, the coal seam #3 was mined out.
With the increased panel width, the width and height of both the fracture zone and bedding zone were increased. In particular the seam #3 was well truly within the bedding zone. Methane from the seam #3 was added to the panel methane extraction system.

4. Results and discussion

4.1. Calculation method of CMM extraction ratio

A methane extraction ratio is defined as follows:

\[
\frac{Q_e}{Q_{GIP}} \times 100\% \quad (1)
\]

Where \( r \) is the CMM extraction ratio (%); \( Q_e \) the total volume of CMM extracted (m\(^3\)); and \( Q_{GIP} \) the total methane in place (m\(^3\)).

CBM exploration often conducts quite a number of coal sample tests to estimate \( Q_{GIP} \) \(^7\)\(^-\)\(^8\). But in coal mines, no the number of such tests are often limited and methane emission in a panel is often empirically estimated based upon local mining condition, local geology, mining sequence, and so on. In YCC district, an empirical equation \(^6\) to calculate methane emission rate is as follows:

\[
q = K_s \cdot K_d \cdot K_g \cdot K_m \cdot \sum_{i=1}^{n} L \cdot v \cdot h_i \cdot \gamma_i \cdot (W_i - W_{ri}) / 1440 + \sum_{j=1}^{S} q_j \quad (2)
\]

Where \( q \) is the methane emission rate (m\(^3\) min\(^-\)\(^1\)); \( K_s \) the coefficient of methane in surrounding strata and between 1.15 and 1.25; \( K_d \) the coefficient of the CMM extraction and between 1.15 and 1.25; \( K_g \) the coefficient of local geology and in the range of 0.8 to 1.5; \( K_m \) the coefficient of mining condition of adjacent panels and in the range of 0.9 to 1.1; \( L \) the panel width; \( v \) the panel advance rate; \( h_i \) the thickness of coal seam \( i \); \( \gamma_i \) the density of coal seam \( i \); \( W_i \) the in-situ methane content of coal seam \( i \); \( W_{ri} \) the residual methane content of coal seam \( i \); and \( q_j \) the methane emission rate from the limestones.

Eq. (2) has been widely used in YCC district and proven to be quite effective. This equation was used to estimate the \( Q_{GIP} \) of the overlying coal seams in the field trial. Eq. (3) can be derived from Eq. (2), as follows:

\[
Q = K_s \cdot K_d \cdot K_g \cdot K_m \cdot \sum_{i=1}^{n} S \cdot h_i \cdot \gamma_i \cdot W_i + \sum_{j=1}^{S} q_j \times 1440 \times \frac{S}{l \cdot v} \quad (3)
\]

Where \( Q \) is the methane emission rate per square meter of the panel; \( S \) the panel area, m\(^2\); \( l \) the average panel width, m; and \( v \) the advance rate of the panel, m d\(^-\)1.

4.2. Comparison of methane extraction ratios with different panel widths

The CMM extraction ratio and panel advance rate at different zones of K8206 are shown in Fig. 4. Two adjacent panels of K8206, i.e. K8108 and K8110, were investigated for their methane extraction ratios. Based on the field conditions, the coefficient of \( K_s \), \( K_d \), and \( K_g \) were selected as 1.25, 1.25, and 1.3 for these three panels and \( K_m \) was estimated to be 0.9 when one side of the panel was mined out and 1.1 when the side of the panel was not mined. Table 2 shows the methane extraction ratios of these three panels.

The results from Table 2 show that the CMM extraction ratio in the zone (I) of K8206, where all of the overlying coal seams were not mined, reached 76.8 %, whereas the CMM extraction ratio at K8108 panel with the similar mining condition was only 53.2 %, an increase of 44.4 % in the CMM extraction ratio. Table 2 also shows that the CMM extraction ratio in the zone III of K8206, where the overlying #3 seam was mined out, was 78.3 %, whereas the CMM extraction ratio at K8110 with the similar condition was 69.2 %, an increase of only 13.1 %. This comparison of the CMM extraction ratios indicates that the connective fracture zone induced by K8206 with a wide
face reached to the #3 coal seam, resulting to a significant increase in its CMM extraction range when all the overlying coal seams are unmined and the ratio didn’t show much different when the #3 coal seam was mined out.

![Graph showing methane extraction rate vs distance and panel advance rate.]

**Fig. 4.** Panel advance rate and CMM extraction rate of K8206

**Table 2.** Comparison of CMM extraction ratios at K8206 and its adjacent common panels

<table>
<thead>
<tr>
<th>Panel</th>
<th>L (m)</th>
<th>Average Qe rate (m³/min)</th>
<th>Qe per sq.m. of overlying reservoirs (m³/m²)</th>
<th>Qn per sq.m. of overlying reservoirs (m³/m²)</th>
<th>4.3 (%)</th>
<th>Mining status of overlying coal seams</th>
<th>Mining status of adjacent panels</th>
</tr>
</thead>
<tbody>
<tr>
<td>K8108</td>
<td>190</td>
<td>63.42</td>
<td>157.86</td>
<td>296.56</td>
<td>53.2</td>
<td>all unmined</td>
<td>one side mined</td>
</tr>
<tr>
<td>K8206(I)</td>
<td>252</td>
<td>157.7</td>
<td>269.00</td>
<td>350.46</td>
<td>76.8</td>
<td>all unmined</td>
<td>new panel</td>
</tr>
<tr>
<td>K8206(?)</td>
<td>252</td>
<td>79.83</td>
<td>197.91</td>
<td>252.63</td>
<td>78.3</td>
<td>coal #3 mined</td>
<td>new panel</td>
</tr>
<tr>
<td>K8110</td>
<td>190</td>
<td>68.9</td>
<td>149.82</td>
<td>216.51</td>
<td>69.2</td>
<td>coal #3 mined</td>
<td>one side mined</td>
</tr>
</tbody>
</table>

4.3. Comparison of coal production with different panel widths

Table 3 shows the coal production from three panels (K8108, K8206 and K8110) of different panel width. From Table 3, it can be seen that although the advance rate of K8206 was slower than that of K8101 and K8110, the coal production from K8206 was 30.4 % higher than that of the other two panels due to its wide face.

**Table 3.** Comparison of coal production at K8206 and its adjacent common panels

<table>
<thead>
<tr>
<th>Panel</th>
<th>L (m)</th>
<th>V (m³ d⁻¹)</th>
<th>Coal production (t d⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K8108</td>
<td>190</td>
<td>3.04</td>
<td>5147.8</td>
</tr>
<tr>
<td>K8206</td>
<td>252</td>
<td>2.67</td>
<td>6825.3</td>
</tr>
<tr>
<td>K8110</td>
<td>190</td>
<td>3.48</td>
<td>5323.5</td>
</tr>
</tbody>
</table>

4.4. Impact of panel advance rate on methane extraction rate

Fig. 5 shows the relationship between the CMM extraction ratein the zone II of K8206 and its advance rate. The CMM extraction rate was calculated with the following formula,

\[ q = \frac{Q}{L \times v} \]  

Where \( q \) is the CMM extraction rate per square meter of coal excavated, m³ m⁻²; \( Q \) the volume of methane extracted per day, m³ d⁻¹; \( L \) the panel width, m; and \( v \) the daily face advance, m d⁻¹.
The results from Fig. 5 show that the lower the advance rate was, the higher the CMM extraction rate was. This may be resulted from a long desorption and extraction time of methane from coal, indicating that the CMM extraction ratio can be increased by decreasing panel advance rate.

5. Conclusions

CMM extraction in China is not only critical to safety of coal mining, but also play a key role in methane resource development. Finding new approaches to maximize the integrated extraction of coal and CMM is of significant benefits to China.

The field trial at LW K8206 in YCC shows that properly increasing panel width can enlarge a CMM extraction range, improve methane extraction ratio and increase coal production. In addition, increasing panel width can also provide an option to reduce the face advance rate, such as in the case of difficult mining conditions, while maintaining the same coal production.

The positive effect of a wide panel width on a methane extraction ratio has significant implications on the integrated coal production and methane extraction in both China and other countries such as in Australian where some coal mines in Illawarra and Hunter Valley regions are operating in gassy multi seams with a panel width of over 350 m.

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References