Reservoir Properties Influence on Gas Emission of 14211 Prepared Mining-Face, in Seam Ⅱ 1 of Xin’an Coalmine, Henan Province

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Abstract

14211 was a prepared mining-face in Xin’an Coalmine, Henan province, and it has not been done any work for mining so far. Geological parameters selected in this paper include seam thickness, burial depth, sandstone ratios in 20m and 40m coal seam roof, gas content and minor faults. With the calculating results of gas emission from 2007 to 2010 in other working faces, this paper interpreted the influence on gas emission of selected geological parameters. The gas emission was combined with characters of micro-cracks, permeability and isothermal adsorption. The results demonstrated that, in 14211 preparing face, there is a negative correlation between the absolute gas emission and 20m-sandstone ratio, while a significant positive correlation between the absolute gas emission and the 40m-sandstone ratio. There is gas conductivity in 20m-sandstone, adjacent to the coal seam roof. And this effect becomes so less indistinguishable in sandstone far away from coal seam that it transforms to the gas-storage effect, which is the same with tight sand and mud stone. Analysis concluded that this phenomenon is intimately associated with macroscopic type of coal and characteristic of micro-crack, isothermal adsorption and permeability.

Keywords: gas emission; reservoir property; prepared mining-face

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1. Introduction

Reservoir property has been used for CBM deliverability analysis. Jiangwei Fu et al analyzed CBM recoverable reserve with the isothermal adsorption method [1]. Zhaoping Meng et al, evaluated reservoir from the point of gas content, gas saturation, permeability, adsorptivity and so on, and the results showed that gas content distribution was mainly associated with coal type, coal rank, coal burial depth, denudation after uplifting and block structure [2]. Shiyue Wu et al researched the relation between pore and crack development degree and coal rank, geological structure in coal seam, advanced theories about gas adsorption, desorption, diffusion and percolation [3, 4]. Jianping Ye calculated the gas content in coal seam through Langmuir pressure, Langmuir volume and reservoir pressure in situ [5]. Leping Wang et al suggested that reservoir evaluation should base on pore structure, permeability, reservoir pressure, burial depth, temperature of coal seam, and moisture capacity, metamorphic rank and maceral of coal, and they also assumed permeability of coal seam determined the gas emission, the burial depth, temperature, moisture capacity and maceral affected the gas content [6]. In the study of CBM occurrence regularity and evaluation of resource potential, Boyer et al held on that the high heterogeneity of desorption rate in the same coalmine indicated the marked difference of CBM recoverability in different blocks, and its distribution law should be paid more attention during CBM exploration and development or in mine gas prevention and control [7-10]. Xuchai Fu et al assumed that gas outburst was associated with geologic succession, coal type, coal rank, coal macro-and micro-crack, gas content, gas saturation, hydrologic geology, burial depth and permeability [11]. Bustin et al evaluated adsorptive capacity to gas of coal, from the adsorptivity of coal matrix [12, 13]. Shengli Zhang et al suggested the main geological factors that determined the CBM recoverability were permeability of coal seam, isothermal adsorption of coal, and gas saturation, with permeability being the predominant effectors [14].

Briefly, previous work has been mainly to simulate CBM well deliverability in laboratory. However, there has been less research about reservoir property influence on gas outburst, so this paper selected Seam Ⅱ in Xin’an Coalmine as the object, investigated the reservoir properties in the light of the macroscopic type of coal, characteristic of coal pore and crack, isothermal adsorption, permeability and so on, and analyzed its influence on gas outburst.

2. Geological settings

The 14211 working face locates in the bottom of the eastern limb, in the 14 district dip, with the upper and lower part independently being the bench pillar of the 14191 working face, which has been extracted, and the 14231 working face, which has not been outlined. And there lies the protective pillars of 12 and 14 districts in the east, the pillars of the boundary between the 14 and 16 districts in the west. With the strike length 701.5m, the inclined length 143m and the coal seam thickness from 0.13 to 14.2m, the recoverable reserves in this working face is 449865.8t. The rugged seam floor of Seam Ⅱ approximately rises from the boundary to the center, with the dip angle ranging from 5°to 11°, averagely in 6°. The fold runs gently, with only a big fault, namely HF1, indicating a simple geological structure. Coals from Seam Ⅱ show in a black powdery state, and in the lithotype point of view, clarain takes the lead, durain comes to the second, belonging to the semibright coal in term of macrolithotype. The absolute gas outburst in the adjacent faces, including the 14221, 14151, 12241, and 14161 working faces, which have been ended in extraction, runs ranging from 3.8m³/min to 5.4m³/min, averagely in 4.6m³/min (Fig.1).
3. Sampling and experimental methods

Fourteen samples were taken directly along the upper- and lower- roadway and in the cut-hole (twelve along the roadway and two in the cut-hole). Micro-crack was observed under microscope, the coal isothermal adsorption characteristic was studied through HCA-1 (made by Chongqing Coal Research Institute, 2009) and permeability was measured by AutoPore IV 9510 (made by America with the measured aperture varying from 0.003μm to 400μm).

Gas emission was calculated the data from 38 drilled wells with CH4 capacity measured of the 108 control wells in the whole block, and counted data from 2007 to 2010 of the gas drainage and that measured during driving. Based on the test and analysis, this paper selected burial depth, coal seam thickness, 20m-sandstone, 40m-sandstone, gas content and fault distribution as the main geofactors of the preparing face 14211. And their influences on the gas distribution were investigated according to the drilling holes information from, and gas emission in situ was calculated through the above counted data of the working faces 14221, 14151, 12241 and 14161, from 2007 to 2010. Totally, there are 3 big faults around the boundary. On the base of the above results, gas emission predictive equation of the 14211 preparing face was established, through the Numerical Theory Ⅰ.

Reservoir properties influences on gas emission were analyzed according to the experiment results and the predictive equation.

4. Results and Discussions

4.1. Influence analysis based on single geofactor

Figs.2 to 3 are separately the relations between gas emission and burial depth, coal seam thickness, 40m-sandstone rate of seam roof and fault, both in the adjacent faces including 14151, 12241 and 14161, and the preparing face 14211.

Relation between burial depth and gas emission:
As the Fig.2.(a) demonstrates, the deepest point, down in the left-hand corner, has the highest gas emission, while in the rather shallow zone, it contains less gas. Relation between coal seam thickness and gas emission:

From the Fig.2.(b) we can see there is a significant increase in gas emission with the increasing coal seam thickness. Points with big coal seam thickness, such as the lower left corner and the upper right corner, have more gas.

Fig. 2. (a) Relation between burial depth and gas emission; (b) relation between coal seam thickness and gas emission

Relation between 40m-sandstone ratio in seam roof and gas emission:

Fig.3.(a) shows a negative relation between 40m-sandstone rate and gas emission. In the lower left corner and the central part of the researched area, the sandstone rate is smaller, however, the gas emission is correspondingly higher.

Relation between fault and gas emission:

As is indicated in Fig. 3.(b), the lower left corner owns the big and intensive faults. That is there is some relation between fault and gas emission.

Fig. 3. (a) Relation between 40m-sandstone ratio and gas emission; (b) relation between fault and gas emission

4.2. Gas emission predictive equation of 14211 prepared mining face

The predictive equation below is established on the base of Numerical Theory Ⅰ.

\[ y = -2.7832885495dl(1) + 15.1354043336dl(2) + 0.9569147444dl(3) - 0.0336566002dl(4) - 0.2798115396dl(5) + 6.3368036683dx(1,1) + 6.6615077784dx(1,2) \]  

(1)

where:
dl(1) is 20m-sandstone in seam roof, quantitative variable;
dl(2) is 40m-sandstone in seam roof, quantitative variable;
dl(3) is gas content, m³/t, quantitative variable;
dl(4) is coal seam burial depth, m, quantitative variable;
dl(5) is coal seam thickness, m, quantitative variable;
dx(1,1) is fault, “category have”, qualitative variable;
dx(1,2) is fault, “category not have”, qualitative variable.

4.3. Reservoir properties influence on gas emission

As can be seen from the predictive equation above, there is negative relation between the absolute gas emission and the 20m-sandstone, which fits well with the theory, however, there is a positive relation between it and the 40m-sandstone, contrary to the theory.

Fig.4 is the isothermal adsorption plot of sample 12201-8. According to the experiment results, the adsorption constant a (the maximum adsorption) has the value 15.1127 m³/t, and b has the value 2.1152; the gas saturation is 69.46%-a little high value, with the critical desorption pressure being 0.7356MP. The week adsorption and the relative high gas saturation indicate that, in the 14211 face, adsorption gas is hard to be desorbed during the depressurization process. There is gas conductivity in 20m-sandstone, adjacent to the coal seam roof. And this effect becomes so less indistinguishable in sandstone far away from coal seam that it transforms to the gas-storage effect, which is the same with tight sand and mud stone.

![Isothermal adsorption of coal sample 12201-8](image)

Fig. 4. Isothermal adsorption of coal sample 12201-8

In term of macrolithotype, coal of 14211 face belongs to semibright coal. As the original texture of coal has been badly damaged (Fig.5.(a)), flax-seed coal and mylonitic coal develop in the whole coalmine, with flaky texture (Fig.5.(b)), which results in the high specific surface and great adorability. And in another aspect, the powdery coal is easily to plug the migration pathway while run with the gas, and this may develop the sudden gas outburst.
As is shown in Fig.6.(a) Primary Pore of 14211 Working Face; Fig.6.(b) Metamorphic Pore of 14211 Working Face) and Fig.7.(a)-(b) (Micro cracks of 14211 Working Face), there are plenty of primary and metamorphic pores, improving the specific surface. Thus, the travelling gas can easily run against the coal matrix and be adsorbed as the intermolecular interactions exist. Observations under microscope reveal that crack develops in the coal samples, with the crack width varying from 10 μm to 100 μm, however, most of the cracks are filled with mineral. As a result of the narrow outlet and the bad communication, gas cannot easily escape from coal pores and cracks.
Table 1 shows the calculation parameters of permeability. And the results reveal that the average permeability of the working face is 0.42 md, a low value, which means gas is hard to emit from crack and pore of coal.

Table 1: Permeability Calculation

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Total Area of Pore (m²)</th>
<th>Volume Median pore Diameter (nm)</th>
<th>Area median pore diameter (nm)</th>
<th>Average pore diameter (nm)</th>
<th>Porosity (%)</th>
<th>Permeability (md)</th>
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</thead>
<tbody>
<tr>
<td>14211-2</td>
<td>17.87</td>
<td>17.9</td>
<td>4.7</td>
<td>10.5</td>
<td>0.05777</td>
<td>0.36</td>
</tr>
<tr>
<td>14211-3</td>
<td>16.54</td>
<td>26.8</td>
<td>4.6</td>
<td>11.5</td>
<td>0.05808</td>
<td>0.42</td>
</tr>
<tr>
<td>14211-10</td>
<td>15.61</td>
<td>37.7</td>
<td>4.6</td>
<td>12.1</td>
<td>0.0569</td>
<td>0.47</td>
</tr>
<tr>
<td>14211-4</td>
<td>16.93</td>
<td>14.8</td>
<td>4.6</td>
<td>9.8</td>
<td>0.05087</td>
<td>0.36</td>
</tr>
<tr>
<td>14211-12</td>
<td>14.63</td>
<td>37.8</td>
<td>4.6</td>
<td>12.3</td>
<td>0.05543</td>
<td>0.52</td>
</tr>
<tr>
<td>14211-2</td>
<td>17.38</td>
<td>19</td>
<td>4.6</td>
<td>10.6</td>
<td>0.05696</td>
<td>0.38</td>
</tr>
<tr>
<td>average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.42</td>
</tr>
</tbody>
</table>

5. Conclusions

- Flax-seed coal and mylonitic coal develop in the whole coalmine, with flaky texture. The powdery coal is easy to plug the migration pathway while run with the gas, and this may develop the sudden gas outburst.
- In Seam II 1, there are plenty of primary and metamorphic pores, with the primary pores mainly being fusinite and semifusinite cavity. The developed cleat and tectonic crack are the foundation for gas occurrence. Because of the high isothermal adsorption constants a and b, reservoir has more ability to absorb more gas. The low critical adsorption pressure determines that gas in coal matrix is hard to escape, which is the main reason why 14211 preparing face has high gas emission.
- The high gas emission but with a low permeability directly lead the 14211 working face to be the major face suffers gas outbursts.

There is a negative correlation between the absolute gas emission and 20m-sandstone ratio, while a significant positive correlation between the absolute gas emission and the 40m-sandstone ratio. There is gas conductivity in 20m-sandstone, adjacent to the coal seam roof. And this effect becomes so less
indistinguishable in sandstone far away from coal seam that it transforms to the gas-storage effect. Contradictory to the theory, there is a weak negative correlation between coal seam thickness and gas emission. From the predictive equation point of view, the correlation coefficient of fault far outweighs that of coal seam thickness, which means that the coal thickness influence on gas emission is frustrated by small faults that extend in the working face.

Acknowledgements

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References