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# The scope of fracture zone measure and high drill gas drainage technology research

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**ABSTRACT**

*In the gas mine or gas and coal outburst mine, the gas in upper corner is the key to the matter of the production safety, and the high drill gas drainage technology is a frequently-use treatment measure in a working face. How to determine the scope of fracture zone is very important to this technology. In this paper, we designed a method to test the scope of fracture zone of different position in working face, according to the arrangement characteristics of working face, furthermore, we verified veracity of the test by field experimentation. The results show that at the different position in the working face, the scope of fracture zone is differently, and with the increase of distance to the return airway, the gas drainage concentration was increasing, the scope of fracture zone was to be higher. With the extracting of the working face, the drainage drills' position will be under to the scope of fracture zone gradually, then, the gas drainage concentration will be reduced.*

**Key words:** Gas control; Fractured zone; High drill; Gas drainage

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## INTRODUCTION

China is a rich in coal resources but poor in oil and gas [1].Coal provides more than 68% of Chinese energy, which is much higher than that of developed countries, and approximately 3660 million tons were produced in 2012[2].

After coal seam was been mined, thetwo classes fractures were formed in the proof.One kind is delamination cracks, is refers to the cracks appeared along the fissures between different rock stratum, because the different lithology and height of strata that lead to different the subsidence. Another kind is the vertical cracks,refers to the across fracture that formed when the tensile shear effect was more than the strength of the rock [3]. Then, there are three zone been distributed in goaf overlying rock, on the vertical direction, they are caving zone, fractured zone, and bend subsidence zone. For a working face, as a result of the existence of caving zone and fracture zone, it will be cause the adjacent coal seam pressure to be relief, and cause the effect of gas flow, then, a large number of pressure relief gas which from the adjacent and surrounding rock will flow directed into the working face [4]. Eventually, there will be lead to a series of gas disaster problem in the working face. Such as gas transfinite and gas explosion.

In a working face, the high drill gas drainage technology was a major measure to control the gas that from the adjacent coal seam and the surrounding rock, and the key of the technology is how to determine the scope of fracture zone. Scholars have performed extensive research and advanced some methods to determine this scope [5-7]. It is widely recognized that the scope of fracture zone is greatly affected by the thick of coal seam, the lithology of overlying rock, and the position of the point in working face. In this paper, according to the field conditions and the geometrical relationship between drill and test point, we made some field test and data analysis, determined the scope of fracture zone of different position.

**THE HIGHDRILLGAS DRAINAGE TECHNOLOGY**

**2.1 theory of high drill gas drainage**

After the coal has been mined, the key strata controlled the upper strata and surface movement [8]. Under the key strata, there is a fracture development zone called "O-shaped circle" that interconnected on the crosswise [9,10]. Obviously, the side of "O-shaped circle" which close to the working face is immobilization, and the other side will keep moving with the working face. The rate of movement is equal to the rate of working face advance. So, the "O-shaped circle" will be always there. Either above or below the "O-shaped circle", in the coal seam influenced by caving, the gas would be transport to the center of "O-shaped circle" under the effect of concentration gradient and pressure gradient. Then, the "O-shaped circle" become to be a main area that the gas gathering and transporting [11].

The high drill gas drainage refers to use the fracture zone formed because the coal caving, in the "O-shaped circle", and the drill hole to drainage the gas in goaf [4,12].

**2.2 Design of high drill gas drainage**

The drill field of high drill gas drainage technology always arranged in the return airway, the drills along with the coal seam, and directed to the working face (fig.1 and fig.2).

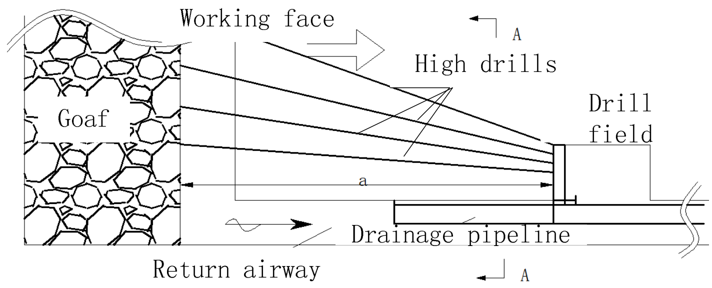



**Fig.1 The plane arrangement of high position drills in working face**

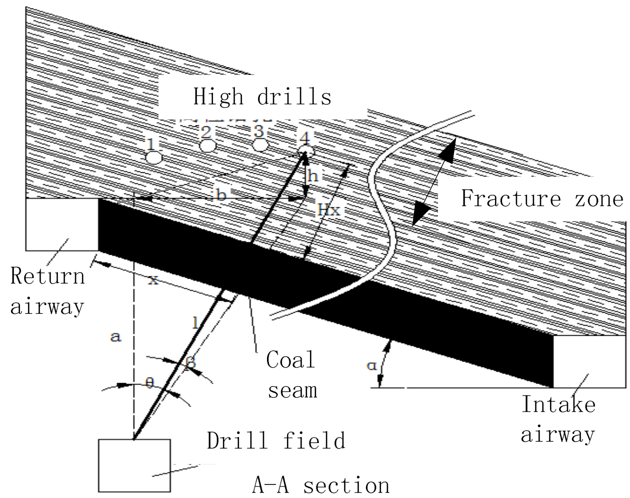



**Fig.2 The sections arrangement of high position drills in working face**

As show in fig.1 and fig.2, $\boldsymbol{a}$ is the distance between drill field and the working face, along with return airway; $\boldsymbol{b}$ is the distance between drills' tail end and the upper corner; $\boldsymbol{h}$ is the height difference between drills' tail end and the upper corner; $\boldsymbol{\alpha}$ is the coal bed pitch; $\boldsymbol{x}$ is the distance between test point at the working face and the upper corner, along with the working face; $\boldsymbol{H_x}$ is the height of fracture zone at the x test point; $\boldsymbol{l}$ is the length of drills.

According to the geometrical relationship, the high drills' length, drift angle($\boldsymbol{\theta}$)and elevation angle ($\boldsymbol{\beta}$) can be calculated by the formulas as follow (based on the center line of return airway):

$$l = \sqrt{a^2 + b^2 + h^2} \quad (1)$$

$$\beta = \arcsin \frac{\mathrm{h}}{\sqrt{a^2 + b^2 + h^2}} \quad (2)$$

$$\theta = \arctan\frac{b}{a} \quad (3)$$

$$b = \frac{x}{\cos\alpha} \quad (4)$$

$$h = \frac{\tan\alpha}{H_x - x\tan\alpha} \quad (5)$$

where, $\boldsymbol{\beta}$ is the elevation angle of drills; $\boldsymbol{\theta}$ is the drift angle of drills.

Takethe formula (4) and (5) into (1), (2) and (3),respectively. Then, the parameters of high drills can be calculated by the formulas as follow:

$$l = \sqrt{a^2 + (\frac{x}{\cos\alpha})^2 + (\frac{\tan\alpha}{H_x - x\tan\alpha})^2} \quad (6)$$

$$\beta = \arcsin\frac{\tan\alpha/(H_x - x\tan\alpha)}{\sqrt{a^2 + (\frac{x}{\cos\alpha})^2 + (\frac{\tan\alpha}{H_x - x\tan\alpha})^2}} \quad (7)$$

$$\theta = \arctan\frac{x}{a\cos\alpha} \quad (8)$$

**Field experimentation**

At present, there are two methods to determine the scope of fracture zone, they are empirical formula and gas volume fraction test. The empirical formula as follow [13]:

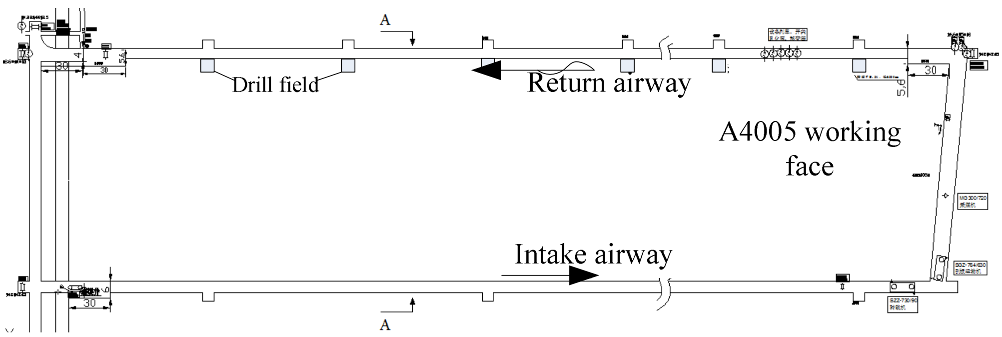
$$H = \frac{100M}{3.1M + 6.0} \pm 6.5 \quad (9)$$

where, $\boldsymbol{M}$ is the height of working face.

**3.1 The situation of working face**

The minable thickness of the 4th coal seam in the mine is 2.67 m, the coal bed pitch is 14°. There is one or two dirt bands in the 4th coal seam, the content of gas is 3.2 $m^3/t$. The A4005 working face located the east area of the mine, the length is 641 m on the trend direction, and the length is 160 m on the inclination direction. The arrangement of the working face is show in fig 3.

According to the geological conditions and production specifications, comprehensive mechanized coal mining method has been adopted in A4005 working face. The designed air volume was 900 m3 per min. In the initial production stage, the gas concentration at the upper corner of A4005 working face is more than 4.6%, and in the depth of goaf the gas concentration is 27%, the gas concentration in the return airway is beyond 1.5%. So, the manager decided to use the high gas drainage technology to control the gas in goaf, which from the adjacent coal seam and surrounding rock.



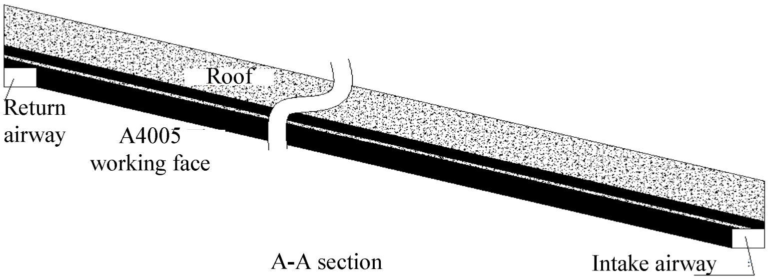



**Fig.3 A4005Working-face arrangement**

### 3.2 Test drills design

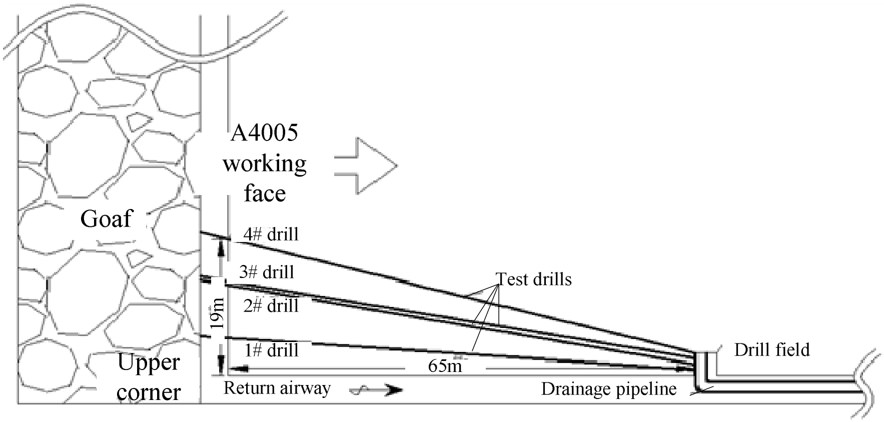



**Fig.4 The arrangement of test high drills**

As shown in fig 4, the distance between upper corner and drill field is 65 m, and the drill field's size (length*width*height) is 3 m*3 m*2.8 m. There 4 test drills are arranged in the drill field, along with the roof, direct to the working face, the dills' diameter is 75 mm. The covered scope of the working face is 19 m. After the 4 drills were executed, connect the drills to the drainage pipeline, and obligate one measure hole on the drainage steel tube in each drill. The parameters of drills as shown in table 1.

**Table 1. The parameters of test drills**

| drill hole | drift angle(°) | elevation angle(°) | length(m) |
|---|---|---|---|
| 1# | 4.4 | 7.5 | 65.8 |
| 2# | 9.6 | 9.3 | 66.8 |
| 3# | 9.6 | 11.5 | 67.23 |
| 4# | 13.8 | 12.5 | 68.47 |

A test period is refers to the working face advanced 3 m, in every test period, we measured the gas concentration in each drainage drill hole, respectively. According to the change of concentration in every drill hole, we can reckon the scope of fracture zone with the difference position in the working face.

## ANALYSIS AND DISSCUSION

The test data as shown in table 2.

According to the data in table 2, we can draw the contour of gas concentration with the different ***a*** and***x***. As shown in following figures.

The fig.5 is the contour of gas concentration based on 1# drill hole test data. It shows that the gas concentration would be maximum value, when the distance is 47~56 m between drill field and upper corner, the distance is 2~2.4 m between upper corner and test point position at the working face. Then the scope offracture zone is 7~8 m.

The fig.6 is the contour of gas concentration based on 2# drill hole test data. It shows that the gas concentration would be maximum value, when the distance is 50~53 m between drill field and upper corner, the distance is 6~7 m between upper corner and test point position at the working face. Then the scope of fracture zone is 10~10.5 m.

**Table 2. The concentration data of the test drainage drills**

| drill hole | *a*/m | $H_x$/m | *x*/m | gas concentration/% | drill hole | *a*/m | $H_x$/m | *x*/m | gas concentration/% |
|---|---|---|---|---|---|---|---|---|---|
| 1# | 65 | 9.54 | 2.77 | 12 | 3# | 65 | 15.66 | 7.42 | 13 |
| | 62 | 9.10 | 2.64 | 17 | | 62 | 14.94 | 7.08 | 15 |
| | 59 | 8.66 | 2.51 | 25 | | 59 | 14.21 | 6.74 | 22 |
| | 56 | 8.22 | 2.39 | 27 | | 56 | 13.49 | 6.39 | 25 |
| | 53 | 7.78 | 2.26 | 26 | | 53 | 12.77 | 6.05 | 25 |
| | 50 | 7.34 | 2.13 | 26 | | 50 | 12.05 | 5.71 | 28 |
| | 47 | 6.90 | 2.00 | 27 | | 47 | 11.32 | 5.37 | 26 |
| | 44 | 6.46 | 1.88 | 26 | | 44 | 10.60 | 5.02 | 27 |
| | 41 | 6.02 | 1.75 | 23 | | 41 | 9.88 | 4.68 | 24 |
| | 38 | 5.58 | 1.62 | 16 | | 38 | 9.16 | 4.34 | 25 |
| 2# | 65 | 13.13 | 8.08 | 11 | 4# | 65 | 18.23 | 11.90 | 16 |
| | 62 | 12.52 | 7.71 | 11 | | 62 | 17.39 | 11.35 | 19 |
| | 59 | 11.92 | 7.33 | 14 | | 59 | 16.55 | 10.80 | 17 |
| | 56 | 11.31 | 6.96 | 23 | | 56 | 15.71 | 10.25 | 25 |
| | 53 | 10.71 | 6.59 | 25 | | 53 | 14.86 | 9.70 | 27 |
| | 50 | 10.10 | 6.22 | 29 | | 50 | 14.02 | 9.15 | 27 |
| | 47 | 9.49 | 5.84 | 23 | | 47 | 13.18 | 8.60 | 29 |
| | 44 | 8.89 | 5.47 | 22 | | 44 | 12.34 | 8.06 | 26 |
| | 41 | 8.28 | 5.10 | 22 | | 41 | 11.50 | 7.51 | 26 |
| | 38 | 7.68 | 4.72 | 21 | | 38 | 10.66 | 6.96 | 23 |

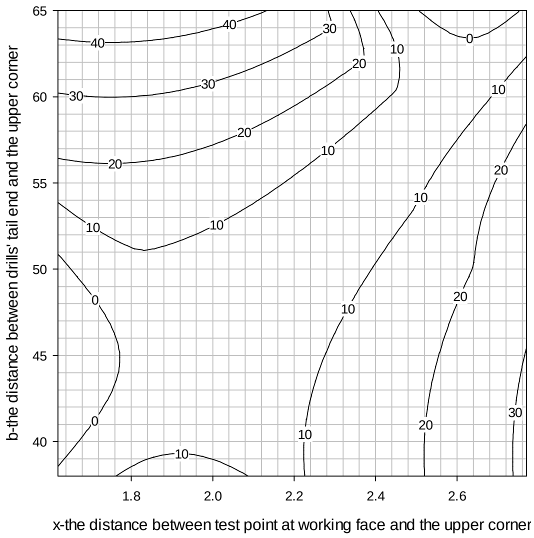



**Fig.5 The concentration contour line in 1# drill hole**

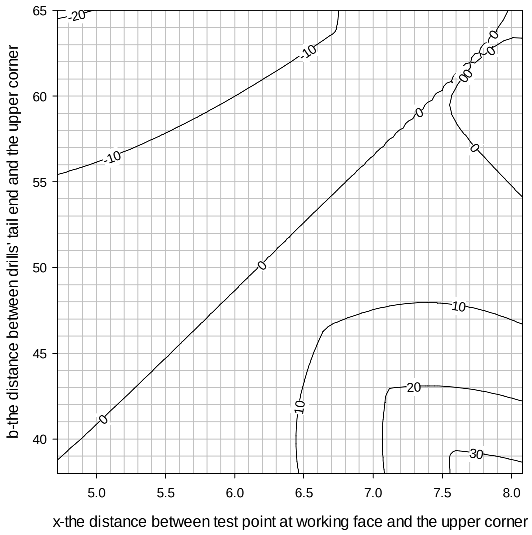



**Fig.6 The concentration contour line in 2# drill hole**

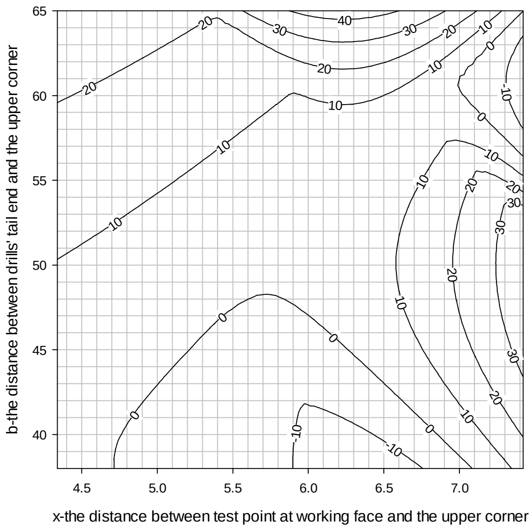



**Fig.7 The concentration contour line in 3# drill hole**

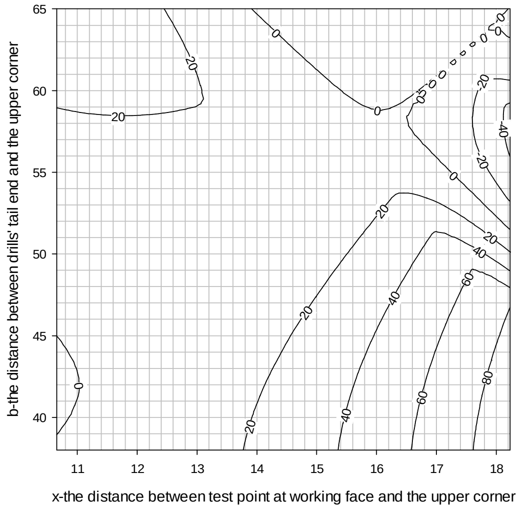



**Fig.8 The concentration contour line in 4# drill hole**

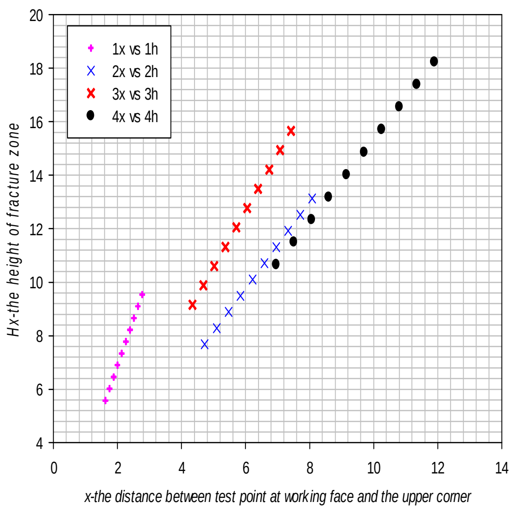



**Fig.9 The height of fracture changing with *x***

The fig.7 is the contour of gas concentration based on 3# drill hole test data. It shows that the gas concentration would be maximum value, when the distance is 44~50 m between drill field and upper corner, the distance is 5~5.7 m between upper corner and test point position at the working face. Then the scope of fracture zone is 10~12 m.

The fig.8 is the contour of gas concentration based on 4# drill hole test data. It shows that the gas concentration would be maximum value, when the distance is 47~53 m between drill field and upper corner, the distance is 8.5~10 m between upper corner and test point position at the working face. Then the scope of fracture zone is 12~14 m.

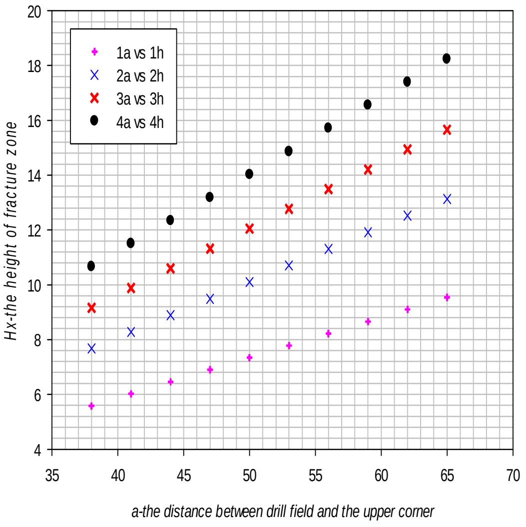



**Fig.10 The height of fracture changing with *a***

With the increase of the ***x***-distance and the ***a***-distance, the scope of fracture zone will be increased also, as shown in fig.9 and fig.10. And these increases trend have the similar rate. In order to be precise grasp the scope of fracture zone, we compared the test scope with the scope calculated by empirical formula. The result is shown in table 3.

**Table 3. The scope of fractured zone**

| ***x***-distance /m | Scope of fracture zone ($H_x$/m) | |
|---|---|---|
| | test value | empirical value |
| 2~2.5 | 9.39~10.39 | 11.32~24.32 |
| 5~6 | 12.39~13.39 | |
| 6~7 | 13.39~15.39 | |
| 12~15 | 14.39~17.39 | |

The table 3 shows that the scope of fracture zone obtained by empirical just given a scope of the scope in totally. The test results have given the different scope value that belong different position at the working face. Obviously, the test values were more in line with the actual situation.

## CONCLUSION

In this paper, we study the geometrical relationship of the drills, upper corner in the working face, the test position in the working face and the scope of fracture zone. The suitable scope of fracture zone is discussed. And the empirical scope of fracture zone is proven not matched the actual situation.

The field experiment confirms that the scope of fracture zone is different with the difference test point in the working face. At last, we gained some conclusions:

(1) With the distance increasing, between upper corner and drill field, and between upper corner and the test point in the working face, the scope of fracture zone will be increased also.

(2) At the different test point, it has the similar rate for the scope of fracture zone

The results of our investigation may supply important guidance for the gas control measure in the working face. Therefore, we can conclude the size of "O-shaped circle" in goal.

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