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Surface borehole synthesis tension deformation fracture time-space rule

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ABSTRACT

In order to release the tension and shear effect of the superjacent rock strata movement during excavation in coal mine, protect the surface borehole case from fracturing fast and make a good use of the surface borehole during goaf methane drawing, a common synthesis tension deformation fracture model was set up based on the synthesis tension effect of the rock strata, and the deformation rule of the surface borehole case with time and space was researched. The results suggest that, to reduce the deformation the surface borehole should be built between the boundary of the stope and the knee of subsidence curve. At the same time, a 3DEC simulation model and an engineering example were carried out to examine the rules of theoretical model. The result suggests that the model and the rules accord to the test and have good building and protection engineering application values to the surface borehole.

1. Introduction

Drawing gas by surface borehole is an effective method in controlling coal mine gas disasters. And the usage of drawing gas is gaining important improvements due to continued usage of surface borehole in coal mine seam gas drawing, disturbance drawing and goaf drawing [1]. But with continued excavation of coal mine seam, superjacent stratum makes great movements that causes fast breakage of the surface borehole case as the workface goes through the well position. This makes goaf gas drawing very difficult and causes wastage of engineering resource.

Nonce which is based on isotropic mechanics of the fracture mechanism for surface borehole cannot solve the stratum characteristics of the well [2]. The analysis of well fracture characteristic and influencing factors usually focuses on the discussion of engineering phenomenon and so on, which cannot be explained well by fracture variety rule [3]. Surface borehole drawing effect achievements are mostly confined in gas flow field pattern [4]. But with excavation of coal seam, the deformation of the surface borehole well is varying continually and its deflection at different positions is different.

So the probability integral method and cascade rock beam theory were made synthesis applying and a surface borehole synthesis deformation fracture model acceptable for any position rock strata was set up. An extensive research on the variety rule for the deformation of surface borehole during the excavation of the coal seam was carried out in order to guide the selection of a position for building a surface borehole and engineering protection [1,5].

2. Synthesis of tension deformation fracture space rule of surface borehole

The deformation fracture of surface borehole under excavation disturbance refer to the rock stratum shear slippage and separation tension with the rock stratum movement. With the key rock strata controlling the rock stratum movement, the rock stratum movement over coal beam will be subdivide based on these rock stratum: On the interfaces among one rock stratum combination shear slippage will occur, the compression deformation will occur in any of the rock strata and on the interfaces between two rock stratum combination the rock stratum separation will occur. So synthesis of the tension-shear deformation for the surface borehole well mainly occur on the interfaces between two rock strata combination, which is the emphasis of our analysis. We referred to literature for shear slippage deformation and compression deformation analyses [6,7].

With the excavation of coal seam, there will be serious separations under the key rock strata (or rock stratum combination), just as shown in Fig. 1. So the tension deformation of the surface borehole case will occur at the separation position, and then the neck will fracture. Based on the separation model, the surface borehole case necking fracture model is just like the mode shown in the Fig. 2.

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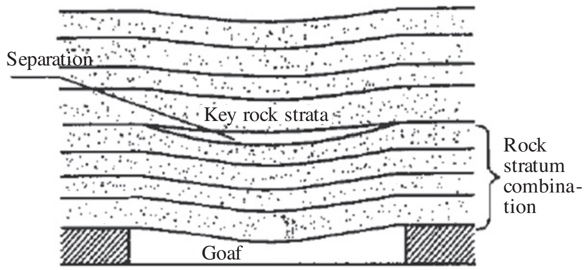

Fig. 1. Strata bed separation model over stope.

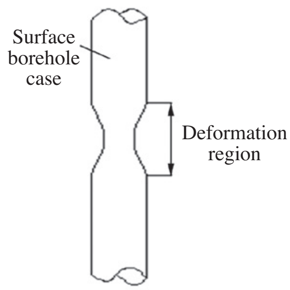

Fig. 2. Surface borehole strata separation deformation style.

Based on the ground subsidence and rock stratum movement rules, the subsidence function at any position of rock stratum over stope will be:

$$w(x,z) = w_{\max}\left(\frac{1}{r_Y}\int_{x_1}^{x_2} e^{-\pi\left(\frac{x-r_Y-s_x}{r_Y}\right)^2} ds_x\right)\left(\frac{1}{r_Y}\int_{z_1}^{z_2} e^{-\pi(\frac{z-r_Y-s_z}{r_Y})^2} ds_z\right) \tag{1}$$

So referring to literature, the separation function on interface between two rock strata combination will be:

$$\Delta w(x) = \left(W_{\max}^{n} - W_{\max}^{n+1}\right)\left(\frac{1}{r_Y}\int_{x_1}^{x_2} e^{-\pi\left(\frac{x-r_Y-s_x}{r_Y}\right)^2} ds_x\right) \times \left(\frac{1}{r_Y}\int_{z_1}^{z_2} e^{-\pi\left(\frac{z-r_Y-s_z}{r_Y}\right)^2} ds_z\right) \tag{2}$$

where r_Y is the main influencing radius on the interface position; $W_{\max}^{n}$ and $W_{\max}^{n+1}$ the two neighbor rock strata combination subsidences displaced by P coefficient computed method; x the stope incline direction; z the stope trend direction; and x_1, x_2, z_1, z_2 the excavation influence borders in the incline or trend direction [8,9].

Suppose the surface borehole well separation tension region length is d, then the critical strain function on the interface between two rock strata combination is:

$$\xi = \frac{\Delta w(x)}{d} = [\varepsilon_{axial}] \tag{3}$$

where ξ is separation tension strain; $\Delta w(x)$ calculated by the Eq. (2); and $[\varepsilon_{axial}]$ the limit of the axial strain which is decided on by the well material and gas drawing efficiency.

Substituting Eq. (1) into (3), the surface borehole well separation tension deformation will gain:

$$\xi = \frac{u_s}{d} = \frac{1}{d}\left(W_{\max}^{n} - W_{\max}^{n+1}\right)\frac{1}{r_Y}\int_{x_1}^{x_2} e^{-\pi\left(\frac{x-r_Y-s_x}{r_Y}\right)^2} \times ds_x \frac{1}{r_Y}\int_{z_1}^{z_2} e^{-\pi\left(\frac{z-r_Y-s_z}{r_Y}\right)^2} ds_z \tag{4}$$

Because of the similar rock characteristics, the length of the surface borehole tension-shear synthesis deformation region is similar on the same rock strata interface. Based on the Hooke law, the separation tension stress variety rule for the stope in the incline direction coincides with its strain variety rule. So from Eq. (2), the separation tension stress, on the interface between two rock strata combination in full subsidence, variety rule in the stope incline direction is just like the rule shown in the Fig. 3.

As shown in Fig. 3, the separation tension displacement in the middle of the stope is maximum which make the separation tension stress maximum. And from the middle of the stope to the double ends of excavation, the influence of the separation tension stress reduces with reduction of the separation tension displacement and gain zero value due to influence of excavation on the border.

At the same time, the surface borehole case shear slippage deformation in stope incline direction is symmetrical to the middle line of stope. The middle line is at the local minimum point and the case shear slippage deformation increase slowly and gain the maximum points at the knee of subsidence curve due to the influence from excavation on both borders. Then the shear slippage deformation reduce fast and gain zero point due to excavation influence on the borders, just as shown in the Fig. 4 [4].

Because the case separation tension strain is usually larger than the macrocosmic tension strain of the shear slippage strain or stress, on the interface between two rock strata combination will mainly coincide with the separation tension strain or stress rule. But the shear slippage strain will make the mode of distribution vary a little which keep the major trend unchanged as shown in the Fig. 5.

As shown in the Fig. 5, the surface borehole synthesis tension stress on the interface between two rock strata combination in stope incline direction gains maximum value at the middle line of stope when subsidence become full. From the middle line of stope to the double excavation influence ends, the synthesis tension stress reduce slowly and then fast after the knee of subsidence curve and gain the zero points on the excavation influence borders.

The surface borehole case synthesis tension stress variety rule in the stope trend direction is similar to that in the stope incline direction. But this distribution is forward continually with excavation of coal beam.

The displacement of rock strata subsidence in the vertical direction will increase with increase of its depth. Referring to the surface borehole case shear slippage deformation rule, macrocosmic tension stress of shear slippage will increase slowly when the thickness of the key rock stratum is uniform [7]. But the separation tension displacement is decided on by the rock stratum lithologic characteristics, thickness and other comprehensive evaluating indicators, therefore, the separation displacement and separation tension stress do not have obvious distribution rules. However, the separation tension stress is the major part of the synthesis tension stress, so the synthesis tension stress is usually large where the separation displacement is large. The safety coefficient is the reverse of the synthesis tension stress distribution rule, that is,

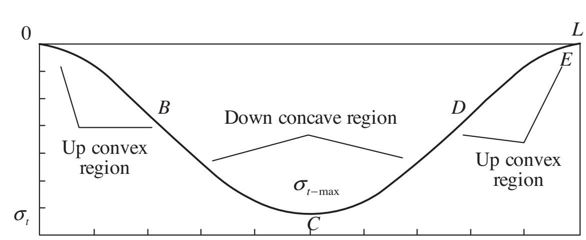

Fig. 3. Separation tension stress variety in full subsidence.