Impact Analysis of the Open Type Crack Characteristics of Coal and Rock Burst

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Abstract. Under the compression state in order to obtain mode open crack behavior of coal and rock burst, based on fracture mechanics analysis of crack open type crack pattern, the study of open type crack crack characteristics, using RFPA numerical simulation software simulation with different open type crack geometry parameters of coal and rock strength and failure characteristics. The research results show that the geometric parameters and load effect on crack open type crack law, the radius of curvature, the greater the Angle of the open type crack in the closer it gets to the DHS 40 ~ 60 DHS, the longer the length, lateral pressure coefficient is smaller, the smaller the crack stress, coal and rock will be easy to burst;Coal and rock strength increases with the increase of content of open type crack length decreases sharply, along with the increase of crack Angle contained present the change trend of increase with the decrease of the first.

Keywords: compressive state; opening-mode crack; the stress of initiation; coal and rock.

1. Introduction

There are a lot of joints and cracks in the coal body, and stress concentration can easily occur at the crack tip under load. When the stress intensity factor reaches the rock fracture toughness, the crack will expand, and the coal body begins to fracture. The existence of cracks reduces the macroscopic strength of the coal body, which can easily cause various engineering accidents [1~3]. Many scholars have conducted a lot of experimental and theoretical studies on the mechanism of crack initiation, expansion and penetration as well as the mechanical characteristics of coal bodies containing cracks [4-11]. Some research results have been obtained, but more in-depth studies on the mechanism are still needed.

Crack can be divided into open type crack and crack closure type, open type crack has certain width, upper and lower surface contains most of the rock crack open type, regardless of under natural conditions or under the condition of artificial prefabricated, to make the rock crack closed completely hard[4], the process of mining, coal and rock exist or have a lot of open type crack, which is closely related to the safe and efficient mining, so the research on the rules of open type crack crack and its influence on coal and rock strength characteristics have important engineering practical significance.

Based on the theory of fracture mechanics, this paper discusses the influence of geometric parameters and load on the crack initiation characteristics of open type crack, and USES RFPA^{2D} numerical simulation software to simulate the strength characteristics of coal body with open type crack, so as to provide reference for safe mining of mining resources.

2. Crack Initiation Rule

2.1. Crack Stress Model

As shown in fig.1, the elliptic open-type oblique crack model under pressure of two axes, the long axis of the elliptical crack is 2a, the short axis is 2b, and the curvature radius of the crack tip is ρ. σ1 and σ3 are distributed evenly on the crack edge, σ3 =λσ1, $0 \le \lambda \le 1$, the Angle between the crack and σ3 is β (the crack dip Angle), and established the rectangular coordinate system xoy.

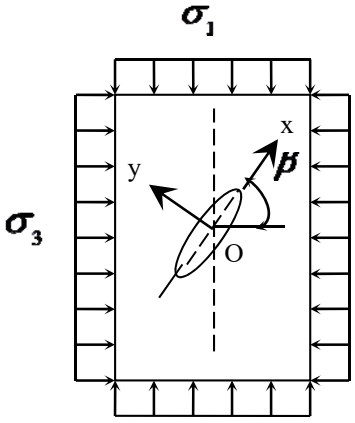


Figure 1. The force diagram of open type crack

According to the elastic mechanics theory, transverse compressive stress σx, normal stress σy and shear stress τxy in the far field of the crack surface can be obtained from the following formula [7]:

$$\sigma_x = \sigma_1\left(\sin^2\beta + \lambda\cos^2\beta\right) \tag{1}$$

$$\sigma_y = \sigma_1\left(\cos^2\beta + \lambda\sin^2\beta\right) \tag{2}$$

$$\tau_{xy} = \frac{\sigma_1(1-\lambda)\sin(2\beta)}{2} \tag{3}$$

2.2. Crack Stress Intensity Factor

As an important parameter of linear elastic fracture mechanics, stress intensity factor characterizes the strength of load and deformation at the crack tip and is a measure of crack growth trend or driving force of crack growth [8].When considering the crack width, the stress intensity factors K_I and K_{II} at the crack tip are [6]:

$$K_I = \sigma_x\sqrt{\pi a}\sqrt{\rho/a} - \sigma_y\sqrt{\pi a} = \sqrt{\pi a}\sigma_1\left(\sin^2\beta + \lambda\cos^2\beta\right)\sqrt{\rho/a} - \sqrt{\pi a}\sigma_1\left(\cos^2\beta + \lambda\sin^2\beta\right) \tag{4}$$

$$K_{II} = (\tau_{xy} - \mu\sigma_y)\sqrt{\pi a} = \frac{\sigma_1(1-\lambda)\sin(2\beta)}{2}\sqrt{\pi a} - u\sigma_1(\cos^2\beta + \lambda\sin^2\beta)\sqrt{\pi a} \tag{5}$$

Formula: μ is the friction coefficient of crack surface.

There is a certain width on the crack surface that is 2b≠0. There is no contact between the upper and lower surfaces of the crack. Therefore, μ=0, the stress intensity factor K_I and K_{II} at the crack tip are:

$$K_I = \sqrt{\pi a}\sigma_1\left(\sin^2\beta + \lambda\cos^2\beta\right)\sqrt{\rho/a} - \sqrt{\pi a}\sigma_1\left(\cos^2\beta + \lambda\sin^2\beta\right) \tag{6}$$

$$K_{II} = \frac{\sigma_1(1-\lambda)\sin(2\beta)}{2}\sqrt{\pi a} \tag{7}$$

2.3. Crack Initiation Stress Solution

According to Criterion for compression shear fracture in zhouqunli, when the crack starts to crack, the stress intensity factor K_I and K_{II} at the crack tip satisfy:

$$\lambda_{12}\sum K_I + \sum K_{II} = K_{IIC} \tag{8}$$

Formula: λ_{12} is the shear coefficient, K_{IIC} is the material constant.

According to equation (6), (7) and (8), the crack initiation stress of open type crack can be calculated:

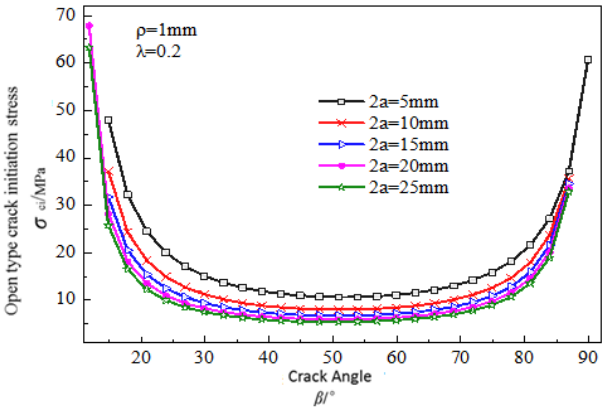
$$\sigma_{ci} = \frac{K_{IIC}}{\sqrt{\pi a}(\lambda_{12}A + B)} \tag{9}$$

Formula:

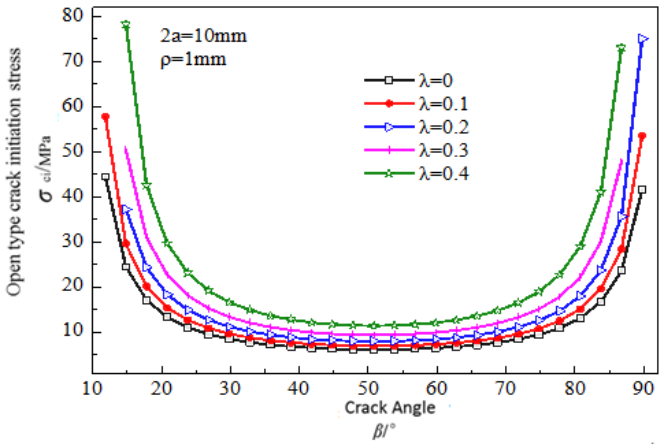
$$A = (\sin^2\beta + \lambda\cos^2\beta)\sqrt{\rho/a} - (\cos^2\beta + \lambda\sin^2\beta) \tag{10}$$

$$B = \frac{(1-\lambda)\sin(2\beta)}{2} \tag{11}$$

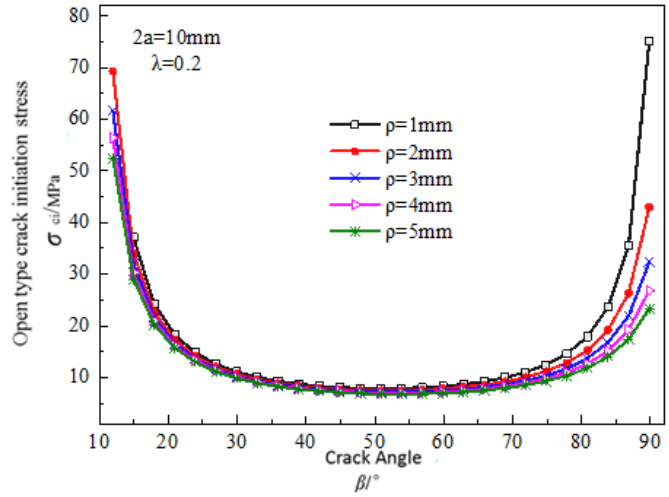
Fig.2 shows the influence law of crack tip Angle β, crack length 2a, lateral pressure coefficient λ and curvature radius ρ of crack tip on crack initiation stress of open type crack. It can be seen that the crack initiation stress of open type crack first decreases and then increases with the increase of crack inclination, and the minimum value is within the range of 40 to 60.With the decrease of crack length, the increase of lateral pressure coefficient and the decrease of tip radius of curvature, the crack initiation stress of open type crack increases slowly.



(a) Stress crack of open type crack trend along with the change of 2a



(b) Stress crack of open type crack trend along with the change of λ



(c) Stress crack of open type crack trend along with the change of ρ

Figure 2. Open type crack crack stress of crack parameters and change trend of the load

3. Numerical Experimental Study on Fracture Process of Coal Body with Open Crack

In this paper, RFPA^{2D} numerical simulation software is used to simulate the strength characteristics of coal body with different open type cracks.The coal body with the following two types of cracks is set successively: one is the coal body with the crack length of 2a=25mm, with the crack Angle of 30º, 45º, 60º and 75º, and the other is the coal body with the crack Angle of β=30°, with the long axis 2a of 0, 5, 10, 15 and 20mm.The fracture characteristics were studied separately. The size of the sample was 50mm x 100mm, which was divided into 100 x 200 cells. The mechanical parameters of the coal and rock mass are shown in table 1.

Table 1. Coal and rock mechanics parameter values table

Parameter	Average degree	Average modulus of elasticity E/MPa	Average compressive strength σ_c/MPa	Within the wiping Angle φ/º
The values	3	41000	12.123	35

3.1. The Simulation Process

The displacement axial loading method was adopted in the numerical test. The loading step was 0.002mm/step. The stress and displacement were automatically recorded during the loading process. Fig.3 shows the whole-process stress-strain curve of the coal body containing open cracks with inclination Angle of β=45º and long axis of 2a=25mm.It can be seen from the figure that when the prefabricated open-type crack in the coal body was compressed, the stress at the crack tip was concentrated, and then the main crack tip cracked and sprouted the airfoil crack.The wing crack of section AB grows stably.In the BC segment, the airfoil crack grew rapidly, and its growth direction was consistent with the maximum principal stress direction.When point C is the peak strength, the wing crack extends sufficiently, the stress field of the coal body is readjusted, and another secondary crack is generated at the crack tip.

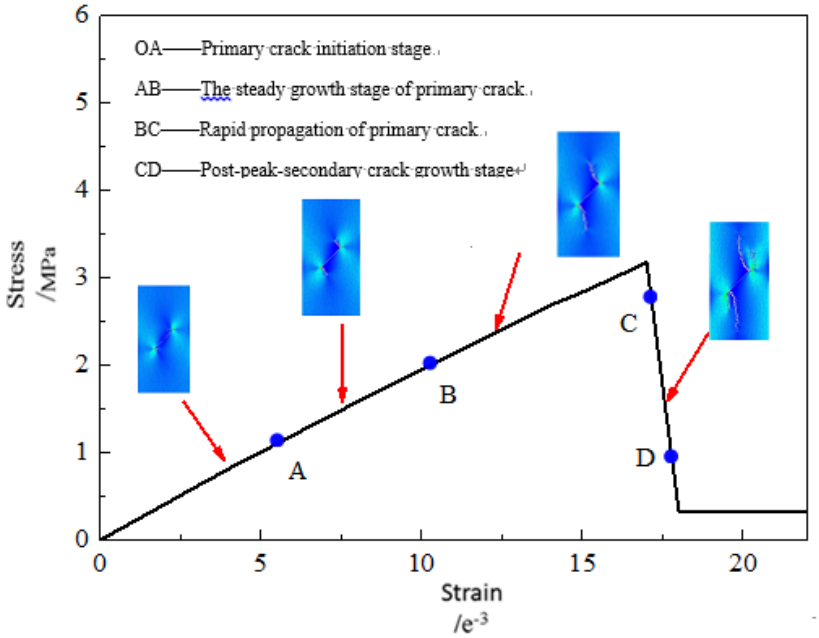


Figure 3. With open type crack of coal and rock stress-strain process curve

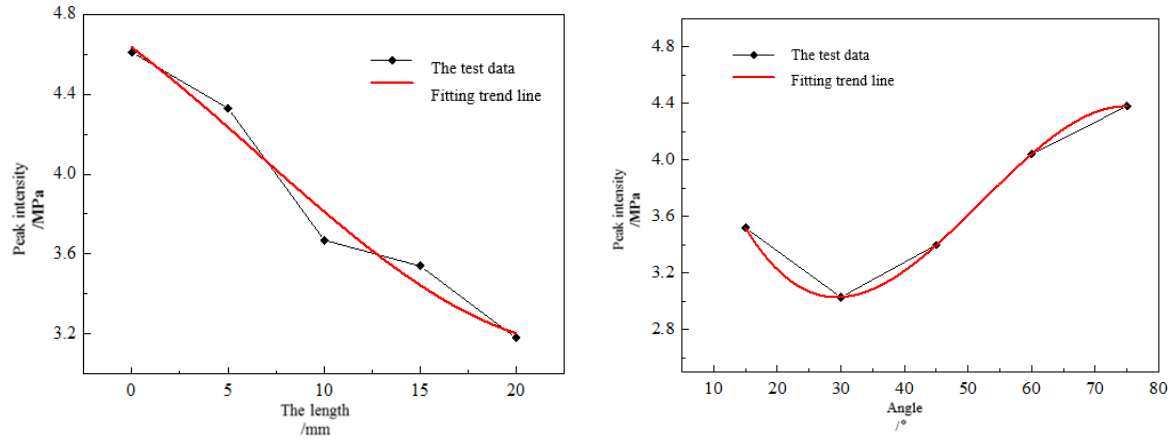
3.2. The Simulation Results

According to the numerical simulation test results, the peak strength of open type crack coal body with different lengths and different dip angles is given in table 2.

Table 2. Open type impact analysis of the crack characteristics of coal and rock burst

0	Angle β/°	Peak intensity σ_c/MPa
0	—	4.61
5	30	4.33
10	30	3.67
15	30	3.54
20	30	3.18
25	15	3.52
25	30	3.03
25	45	3.4
25	60	4.04
25	75	4.38

FIG. 4 shows the variation trend of the strength of the coal body with the geometric parameters of the open type crack. Combined with table 2, it can be seen that the length of the crack in the coal body has a significant impact on its strength.The crack length is in the range of 0~20mm, and the strength of coal body decreases rapidly with the growth of crack length, from 4.61MPa of 2a=0mm to 3.18MPa of 2a=20mm, with a decrease of 23.6%.Crack Angle is different, have different intensity of coal and rock, along with the increase of crack Angle contained in β<30°, the coal and rock strength significantly decreased ; When β=30°, the minimum strength of coal or rock, the minimum value of 3.03MPa ; When β>30°, the coal and rock mass strength along with the increase of Angle presents a gradually increasing trend.



(a) Different crack length (b) Different Angle of crack

Figure 4. Coal and rock mass strength with the change trend of open type crack geometry parameters

4. Conclusion

(1) The closer the inclination Angle of the open type crack is to 40 and 60, the longer the length, the larger the radius of curvature, the smaller the lateral pressure coefficient, the smaller the crack initiation stress, the easier the crack initiation.

(2) The tensile crack length and dip Angle of the coal body have a significant influence on the strength of the coal body. The strength of the coal body decreases sharply with the growth of the crack length.

Acknowledgments

This work was financially supported by the national key research and development program of China (2017YFC0804206).

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